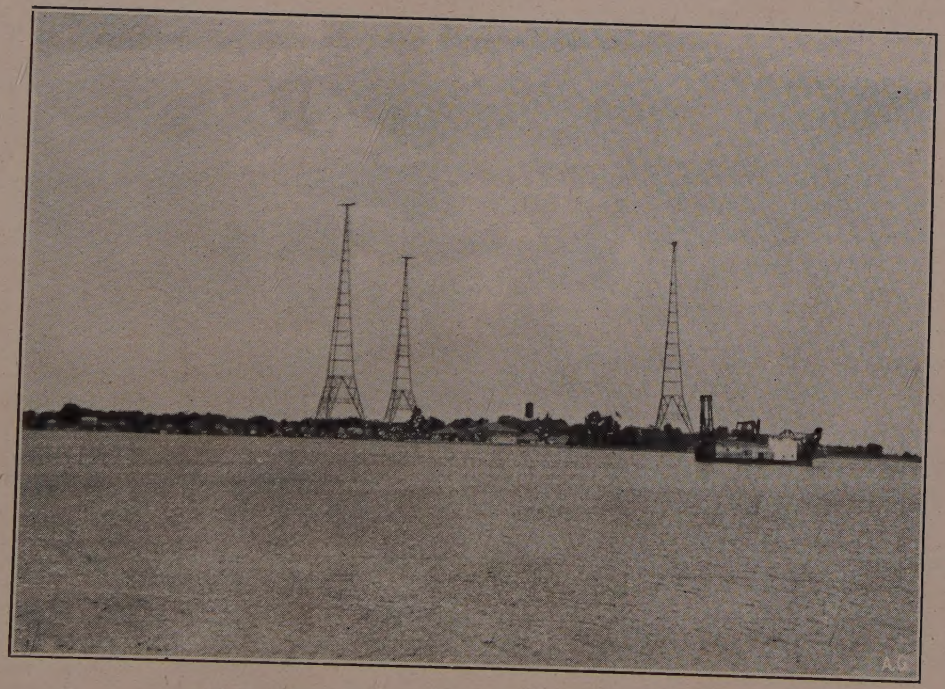
RADIO

IN THE

PHILIPPINES

BY

FRED JOHNSON CLARK



RADIO TOWERS AT CAVITE NAVAL STATION

RADIO

IN THE

PHILIPPINES

BY

FRED JOHNSON ELSER

1925

Copyright applied for

by

FRED JOHNSON ELSER

Printed by
SUGAR NEWS PRESS
Manila

PREFACE

The need for an elementary treatise on the principles of radio communication has long been felt in the Philippine Islands. The writer feels that this volume fills the need for discussion of that portion of Radio which appeals to the public in general; and he has intended to give only information that will be of direct help to the reader: the neophyte broadcast listener and amateur. The desire to be benefited by radio is presupposed, thus no attempt has been made to extol the subject. Mathematical formulas and equations have been eliminated to as great an extent as possible and when given, are presented without proof, which is (in a text of this nature) unnecessary, and tends to confuse the subject matter.

Peculiar conditions, which the writer has observed in these Islands, are presented in as full a manner as possible.

It is hoped that the expectant radio receiver buyer or user and the prospective amateur will be benefited by this little volume.

FRED JOHNSON ELSER.

Manila, P. I.
May 31st, 1925.

CONTENTS

	Page
Chapter I.—Radio Reception	7
Chapter II.—Principles of Radio Propagation	42
Chapter III.—Antennae and their Construction	53
Chapter IV.—Simple Transmitters	72
Chapter V.—The Radio Telephone	93
Chapter VI.—Formulas and Regulations	116
Index	133

CHAPTER I

RADIO RECEPTION

The prospective radio purchaser, who has had no previous experience in selecting apparatus, will find that the problem of choosing a receiver best suited to his needs, is, seemingly, a confusing one. It will, however, be quite simple if one gives it a small amount of study; bearing in mind just what is expected from the receiving apparatus. It may be stated as a general rule that, while the more expensive types of equipment appear to increase the effectiveness of reception (Distance, Tonal quality, etc.), a well constructed single tube receiver, using an outside antenna, and employing the feedback, or "regeneration" principle, will, on headphones, prove the equal of any type of receiver that has been placed on the market so far.

However, a large percentage of radio listeners do not care to go to the trouble of erecting an outside antenna (which is also impossible in some cases: as for dwellers in apartment houses, etc.), nor do some desire to wear the headphones, which are often uncomfortable and permit only one person at a time to hear the programs.

The following classifications will give the reader a general idea of apparatus now on the market, as well as the possibilities of each type:

A. CRYSTAL RECEIVERS. Depend for their operation on the rectifying properties of a piece of crystallized mineral, hence the name. Usually a very simple set, having only one or two controls to adjust. Are the lowest priced outfits obtainable and

need no batteries for operation. Give very clear music and anyone can learn to adjust them in a short time. Their defects are that they can only be used within about ten miles of a broadcasting station, and that outside antennas are needed. They do not give volume enough to operate a loud-speaker and must be used with headphones.

If a "two stage" audio frequency amplifier is connected to the output, they may be used to operate a loud-speaker, but the range of reception will remain the same and the owner will have to pay a certain sum of money every few months for electricity to operate the amplifier. This electricity may be supplied in the form of dry batteries which last for about six months, or storage batteries, which last for about two years, but must be recharged every month, or by a battery "eliminator" which is a device that automatically rectifies the alternating current in the house and renders it fit for radio use. The main objection to this last device is its initial cost.

B. RECEIVERS EMPLOYING ONE "AUDION" TUBE. Sets of this kind use, instead of the "crystal", a tube which increases their range. This tube performs the same function as does the crystal, but in a different manner, which allows better results to be obtained. Tube receivers are broadly divided into two classes:

1. *Tubes Using Regeneration* (*feed back*). This type of set involves a patented process and only a few manufacturers are authorized to make use of it. This explains why some sets do not employ this excellent principle. Those who do use it, have to pay for the use of the patent so this adds an additional cost to the set. Receivers using this principle always have at least two main controls and sometimes many more. The other

controls operate extra apparatus that makes the set more "selective"; that is, more able to hear one station only, when several are operating at the same time. A set of this type, of good construction, will give, if used with an outside antenna and headphones, as efficient service as will any other set now on the market. It will receive broadcasting stations over distances of several hundred miles in the daytime and much more at night or when in the hands of a skilled operator. If too much feedback ("regeneration") is not used, the music will be as clear as with the crystal detector, and much louder. It is an excellent set for both short and long distance reception.

This receiver (or any other employing "audion" tubes) requires a source of electrical energy. The different sources of current supply, and their advantages and disadvantages, have been taken up in speaking of the audio frequency amplifier for the crystal receiver. These sources are applicable to any "audion" tubes. Another disadvantage pertaining to "audion" sets in common is that the tubes "burn out" or become inactive thru other reasons after about a year's usage and new ones must be supplied. The single tube receiver will not operate a loud-speaker without an audio frequency amplifier, and, even with this latter device, needs an outside antenna.

2. *Tubes Without Regeneration.* This set is of a similar type to the one just outlined, the main difference being that signals will be somewhat weaker, and the distance of reception a fraction of that obtained with the "regeneration" type. The notes concerning current supply, etc., are also applicable.

C. RADIO FREQUENCY RECEIVERS. An audion receiver employing one tube, either with or without *Audio Frequency* amplification will operate only when a certain amount of energy is fed into it. If this amount is not fed into the tube no signals will be heard, no matter how much *Audio Frequency* amplification is employed. If the receiver is distant from the broadcasting station or is situated in an unfavorable location, the amount of energy picked up by the antenna will be too small to work the tube and some means must be found to increase this energy locally. The *Radio Frequency* amplifier is the solution of this problem. It increases the energy picked up by the antenna to such an extent that the tube, known as the "Detector" tube, will respond to it. The *Radio frequency* amplifier will not make the music louder; it merely increases the effectiveness of the receiver. The *Audio Frequency* amplifier is then employed to make the signals loud. *Radio Frequency* amplification is secured in a number of ways, which are enumerated below:

1. *The Reflex Receiver.* One of the disadvantages of the radio frequency amplifier is that it adds more tubes to the receiver and a greater current supply is necessary, thus adding to the cost of the installation. To overcome this, a combination of instruments has been devised that makes use of the same tubes both for radio frequency amplification and for audio frequency amplification. The "Detector" may be either a crystal, or a tube with or without regeneration. This type of apparatus proves the cheapest means of securing *Radio Frequency* amplification. It is perhaps slightly harder to adjust than any of the types heretofore mentioned, but this is not to be wondered at, considering the much greater complication which

has to be assumed to attain the objective. *Reflex* receivers may be constructed using only one tube and a crystal detector, but most of the commercial types make use of three or more tubes. *Reflex* receivers are very sensitive and may be used with a compact antenna. The type called the "loop" antenna and resembling a spiderweb, may successfully be employed, if it measures at least two feet on a side, and the set itself has at least one stage of *Radio Frequency* amplification. If at least one stage of *Audio Frequency* amplification is also available, the installation may be used to actuate a loud-speaker, thus dispensing with the troublesome headphones.

2. *The Straight Radio Frequency Amplifier.* Some manufacturers do not reflex their tubes but prefer to use each tube for one purpose only. They then employ a separate tube for each stage of radio frequency amplification, one tube for detection and one tube for each stage of audio frequency amplification. Furthermore, for use at the short wavelengths on which broadcasting is done, some arrangement must be made to neutralize the capacity of the tubes. Receivers employing straight radio frequency amplification generally use a resistance to effect this neutralization.

This receiver probably gives better tonal quality than those sets wherein the tubes perform a double duty, but this is about the only advantage to be obtained. Many controls are needed, and this type of set is, generally, not as sensitive as those employing some other system of attaining this amplification. The set may be employed with the "loop" antenna and, with proper audio frequency amplification, will operate a Loud-speaker.

A current supply is needed, as in all sets employing "audions". The amount of current necessary will depend upon the number of audions used.

3. *The Neutrodyne.* This very popular receiver is another branch of the radio frequency family tree. Instead of using a resistance to keep the radio frequency amplifiers from oscillating, it employs a more efficient arrangement, which does not give rise to such losses. The neutrodyne may be reflexed or not and upon this depends the number of tubes used. As a rule this receiver has three controls, which are all proportional to each other. The settings of these controls may be plotted and reference made to the notes when a certain adjustment is required for the second time. In common with the rest of the radio frequency sets this one may be employed with a loop antenna and if proper audio frequency amplification is available, will operate a loud-speaking device, under that condition. Of course, in all these sets, an outside antenna may be used, giving greater signal strength and in some cases, greater range, but at the loss of selectivity, i. e., the ability to readily differentiate between several broadcasting stations when operating at the same time. These sets are usually quite expensive as compared with some of the types already discussed but fulfill the cardinal requirements of a good radio receiver: *Range, Volume, Selectivity.*

4. *The Super Heterodyne.* This last development in the field of radio frequency makes use of an entirely new principle which has not heretofore been contemplated in this discussion. The complete receiver is undoubtedly the most sensitive known and achieves results that are little short of astounding. Describing the crystal receiver as the "Ford" of radio reception, for the purpose of comparison the super heterodyne

receiver may appropriately be called the "Rolls-Royce". It employs radio frequency amplification but, unlike the other receivers just described, does not amplify at the low wavelengths upon which broadcasting is done, and upon which available "audions" are defective, for this purpose at least.

The arrangement of apparatus, which was invented during the late world war, makes use of a device which changes the low wavelengths (relatively speaking) used in broadcasting, to a much higher wavelength (usually about 6,000 meters), at which much better operation may be obtained from tubes and transformers as available today. These high wavelengths are, therefore, amplified with great efficiency by the radio frequency amplifier supplied with each super heterodyne, and are thus magnified all out of proportion to the feeble signals which originally impinged on the antenna. They are then detected with a suitable audion and may be passed through an audio frequency amplifier to give them sufficient volume to satisfactorily operate a loud-speaker.

Thus we have a set that may be operated, if desired, with only two controls without appreciable loss of selectivity, for so sensitive is the receiver as a whole that a loop of microscopic proportions (when compared with the extensive antenna systems used with most receivers) may be used without loss of efficiency. The loop naturally does not pick up unwanted signals and so, unlike large antennas, does not force them thru the receiver by their mere "momentum". An outside antenna is not desired for use with a super heterodyne except in remote places, where chances of nearby interference are very slight. The set will operate a loud-speaker and may be made semi-portable.

A set of this type has been placed on the market by the Radio Corporation of America. This particular set is noted as a definite example of this development in the radio receiving line. It employs six audions, which are intended to be operated by dry cell batteries; provision for the disposal of same being made in the same box that contains the apparatus. The loop antenna is also mounted within this box. Two controls on the front of the panel, with a button to turn the set on and off and one to control the volume are all the adjustments that are necessary to make. The Loud-speaker is external. The defects in the set, are, of course, its high cost and the large amount of current drawn by the tubes.

SELECTION OF APPARATUS

Having gone over the various possibilities in the receiver line, the reader is now prepared to ask himself the following questions:

1. *How much am I willing to spend for my Radio Receiver?*
2. *How far am I from the Broadcasting Station I want to hear?*
3. *Do I want to listen with Headphones or a Loud-speaker?*
4. *Can I put up an outside Antenna?*

These four questions comprise the key to the whole situation. The first is answered by the ratio between the reader's inclination and the capacity of his pocketbook. Receiving sets may be obtained costing between ₱15.00 and ₱1,000.00. Above five or six hundred pesos, however, the purchaser is not paying for good receiver operation; he is merely buying a handsome cabinet, gilded panel, or other trimmings. The second question is easily answered and determines

what class of set the purchaser *must* buy to hear the programs. If one is within ten miles of a broadcasting station, the minimum amount one is required to expend is ₱15.00, whereas if one is from twenty to fifty miles away, the minimum cost is, probably, about ₱100.00. Those living farther away must pay more, in proportion to the distance. A good 500-watt broadcasting station can only be heard 500 miles in daytime, even with the most sensitive equipment, but the night range of the same station may be ten times as great. The third question, assuming that the reader has decided what set will give him satisfactory reception on the headphones, is merely a question of determining whether he wishes to pay extra for the Loud-speaker and the two-stage amplifier (audio frequency) necessary to operate it. Question number four is not hard to answer either. Put up an outside antenna by all means, if possible, except with a super heterodyne receiver.

We have gone over the major details of selecting the apparatus. Let us now examine a hypothetical case: You, the reader, reside in the provinces, at a distance of one hundred miles from the Manila broadcasting stations. You are willing to pay ₱300.00 for your complete outfit and wish to have the music come in on a Loud-speaker so you can dance to it and let the family and your friends listen to the speeches, market quotations, and talks. You can put up an outside antenna.

Now, beginning from the end and working backwards, we see, first, that you need the Loud-speaker. Purchase one made by a reputable manufacturer, trying it out in comparison with as many others as possible. It is the Loud-speaker that makes the sound

you will hear, so choose it very carefully. Next, you must have a two-stage audio frequency amplifier to make the signals strong enough to operate the Loudspeaker. This can be purchased separately, or, in some cases, as an integral part of the complete set you are planning to buy. There are several kinds of audio frequency amplifiers, the most popular of which employ transformers, others employ resistances and choke coils, which are not as efficient as the transformers but have better tonal qualities. You will do well to insist on having transformers with a low "turn-ratio", about 4-1 is good. In any case try to have the amplifier demonstrated to you under actual working conditions. Now for the receiver: Looking over the different types just enumerated you will find that the single tube set (B-1) will give efficient service at your distance from the broadcasting station, if used with an outside antenna. It is also the least expensive set for your distance. Pick out the set that is easiest for you to operate and performs best under test. Purchasers should buy their sets subject to approval, if possible, and then test them out under actual operating conditions at their homes. As each set is furnished with detailed instructions for care and operation, no attempt will be made here to take up this subject.

Reputable manufacturers when making sets for this climate, always impregnate all delicate coils and apparatus in wax or a similar weather proofing substance, and this impregnation should be made one of the conditions of purchase. The writer has seen coil after coil burn out in this climate, because this simple precaution was not observed. The purchaser must be warned against disregarding the instructions

given him in his handbook accompanying the set he bought, or by the dealer making the sale. The application of excess voltage, or similar careless use of the apparatus, altho giving seemingly better results for a short time, will probably soon lay the set up for repairs.

Now taking up the subject of reception more in detail, the writer will present the simple theory and then give the reader some simple circuits and explanations of a few of the outstanding types of receivers just described.

The Resonant Circuit. Many of my readers, who have had high school or college training, doubtless remember the physics experiment wherein three tuning forks, two of the same pitch, and one slightly different, are placed close together. One of the tuning forks of equal pitch is struck. The other tuning fork of equal pitch will at once begin to sing, but the one of slightly different pitch will remain silent. Those readers who have not had the opportunity to perform or witness this experiment, can make it with thin water glasses of the same size. If two of these glasses are filled with the same amount of water, they will behave as do the tuning forks. In this case, the vibrations of the tuning fork "A" (Fig. 1) will set in motion the nearby air. Some of the molecules of air will bump against the forks of "B", which has a pitch, or natural period of vibration the same as "A". This small amount of air pressure will tend to force the prongs of "B" to start vibrating. Each succeeding pressure of air molecules, being exactly in step with the vibration of "B", will tend to increase the motion, and in a very short time "B" is vibrating at the same pitch as "A". Let us now take the case of the tuning fork "C". This vibrates at 3/4 the speed

of "A" or "B". (See curves, Fig. 1.) It can readily be seen that even if this fork is started vibrating by an original impulse of air molecules from fork "A", each succeeding impulse from "A" will meet the forks of "C" at some fraction of their complete swing.

Let us take the analogy of a person seated in a rope swing. If the swing is given regular pushes each time it has gone forward and come back, the swinging motion may be sustained indefinitely. On the other hand, if a push is given the swing when it is only half way back on its return, this push will tend to stop the swing. This is what occurs in the case of tuning fork "C". Instead of vibrating in step with "A", it remains motionless due to opposing forces. If, however, the amount, or temper, of the metal used in constructing "C" could be altered, that is, if its size could be altered, a point would be found where "C" would respond to the air wave impulses from "A". When this state was reached, "C" could be said to be in tune with "A".

Radio transmission and reception has the same fundamental principles. Instead of "A", let us assume a broadcasting station. Instead of "B" and "C", let us assume two receiving sets of which "B" is tuned to hear the broadcasting but "C" is not. The "Ether", an undefinable material pervading all space, takes the place of the air. Now, the broadcasting station "A" (Fig. 2) sets up waves in the ether. These waves correspond to the music or speeches that are being broadcasted. These "ether" waves travel in every direction and some of them strike the receiving station "B", setting the same, figuratively speaking, in motion. Some of them also strike station "C", but, for much the same reason as outlined in the case of the tuning forks; "C" remains inoperative. Now,

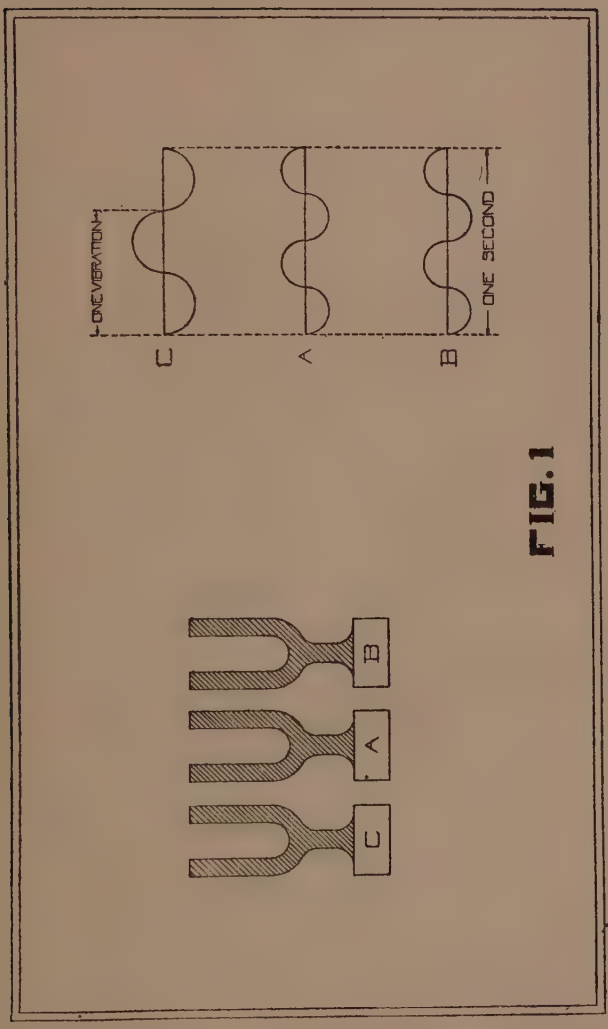


FIG. 1

THE RESONANT CIRCUIT

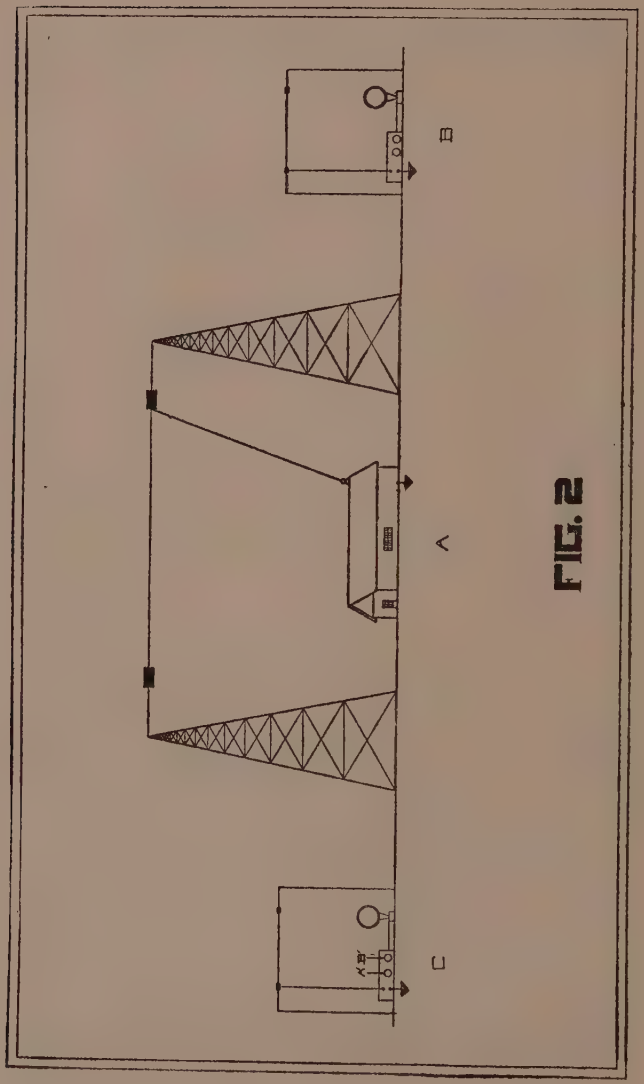


FIG. 2

TUNING TO RESONANCE

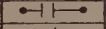
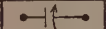
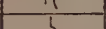
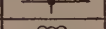
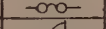
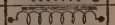
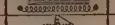
DESCRIPTION OF SYMBOL	SYMBOL	CORRESPONDING LETTER
ANTENNA		ANT.
GROUND		GND.
COUNTERPOISE		CPS.
LOOP		
INDUCTANCE [AIR CORE]		L
INDUCTANCE [AIR CORE] VARIABLE		L
CONDENSER [FIXED]		C
CONDENSER [VARIABLE] SHOWS PLATES MOVABLE		C
WIRES CROSSING NOT TO BE JOINED		
WIRES CROSSING TO BE JOINED		
TELEPHONE RECEIVERS		TEL.
LOUD SPEAKER		LS
AIR CORE COUPLING DEVICE		P-PRIMARY S-SECONDARY
AIR CORE COUPLING DEVICE [VARIABLE]		T
AIR CORE COUPLING DEVICE P AND S [VARIABLE]		T
CRYSTAL DETECTOR		DET.
AUDION TUBE		V.T.
ELECTRIC CHEMICAL CELL		
" " BATTERY		
FIXED RESISTANCE		RESIST.

FIG. 3

CONVENTIONAL RADIO SYMBOLS

DESCRIPTION OF SYMBOL	SYMBOL	CORRESPONDING LETTER
VARIABLE RESISTANCE		R
IRON CORE INDUCTANCE		L
IRON CORE TRANSFORMER		T
VARIOMETER		VM.
TELEPHONE JACK		
VOLT METER		VM.
AMMETER		AM.
MILLI AMMETER		MA.
ALTERNATING CURRENT GENERATOR		ALT.
DIRECT CURRENT GENERATOR		DC GEN
SPARK GAP		
KEY OR SINGLE POLE SWITCH		SW
SINGLE POLE DOUBLE THROW SWITCH		SW

NOTE — A SYMBOL HAVING AN ARROW PASSING THRU IT INDICATES THAT THE INSTRUMENT THE SYMBOL REPRESENTS IS VARIABLE. TWO SYMBOLS HAVING THE SAME ARROW PASSING THRU BOTH ARE VARIABLE WITH RESPECT TO EACH OTHER. THE MICROFARAD ABBREVIATED Mƒ IS THE PRACTICAL UNIT OF CAPACITY. THE OHM ABBREVIATED IS THE UNIT OF RESISTANCE.

FIG. 3

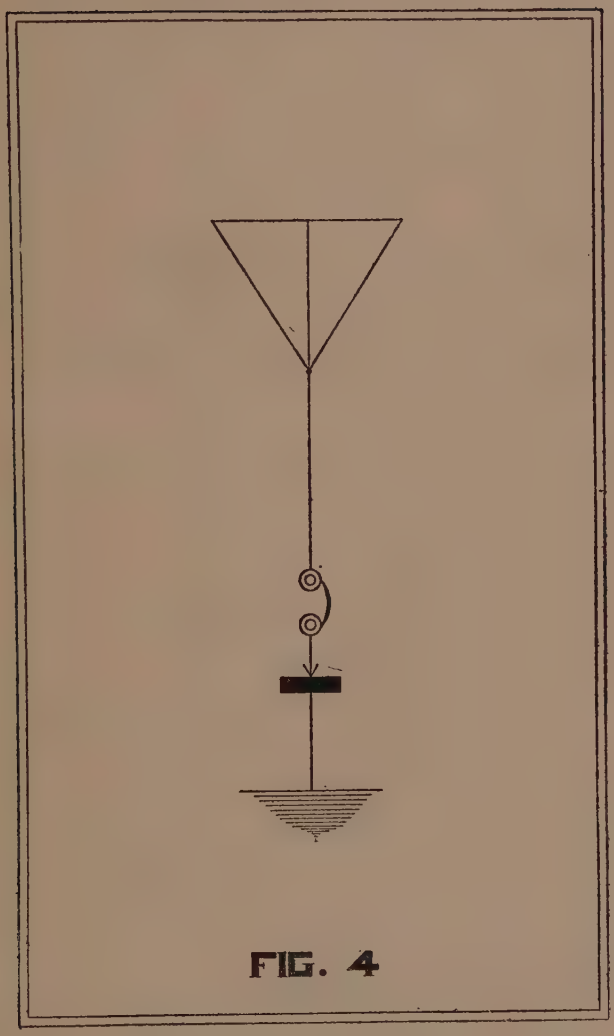


FIG. 4

SIMPLEST RECEIVER

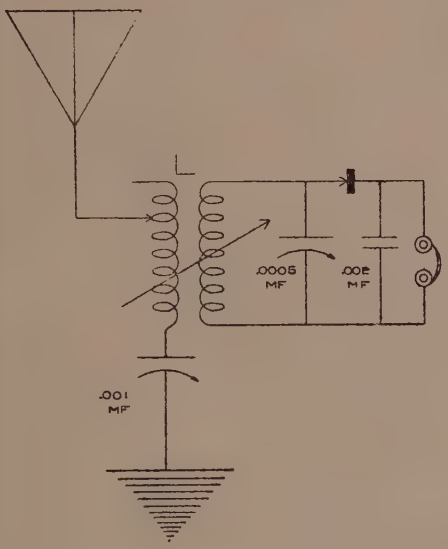
if an operator at station "C" adjusts the controls "a′ " and "b′ ", he will discover a point where he can hear the broadcasting from "A". This adjusting of the controls "a′ ", and "b′ ", is analogous to changing the size of tuning fork "C". (Fig. 1.) When the operator hears the broadcasting he has, in effect, merely altered the size of his receiving system until it corresponds with "A".

At this point, and before proceeding with the various circuit diagrams and descriptions, let us look at Fig. 3 and become acquainted with the various signs used in circuit diagrams. These are all standard and will enable us to read radio connection diagrams much as blueprints are read.

CIRCUIT DIAGRAMS AND EXPLANATIONS

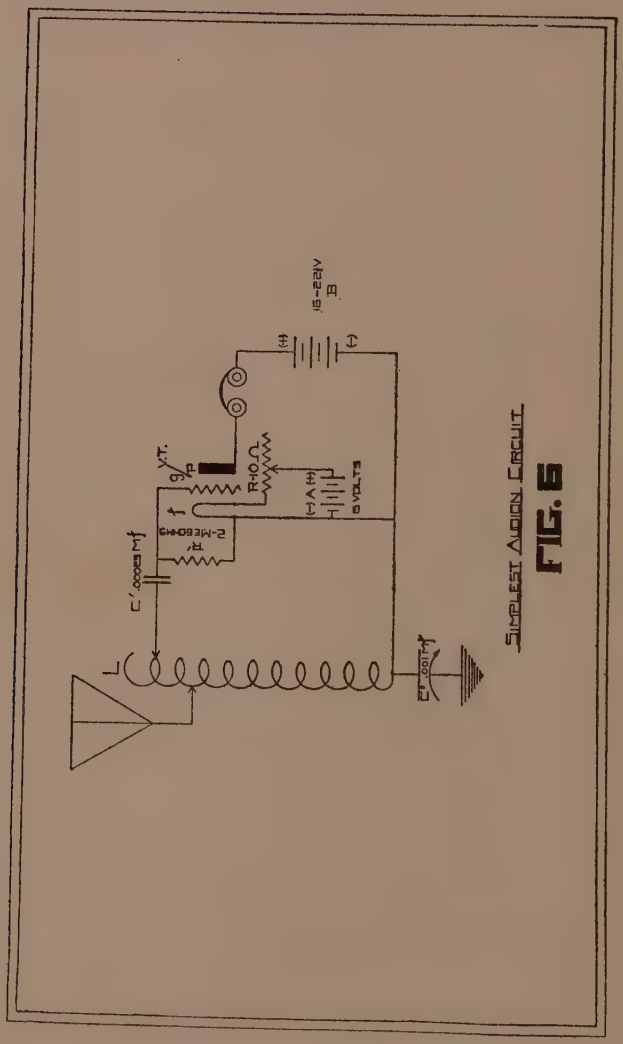
I. *Simplest Receiver.* In Fig. 4 we have the simplest receiver with which it is possible to hear radio telegraph and telephone stations. It is purely an experimental "hook up", wherein an antenna, pair of phones, and a crystal detector are all connected in series and to the earth, or "ground". The only adjustment is of the crystal detector and when this is set for maximum sensitivity, no means are at hand for tuning out undesired stations. The wavelength to which the device responds is entirely dependent upon the length of the antenna used and its range depends upon the sensitivity of the crystal detector. Most of the "freak" sets seen in the illustrated sections of the daily press use this system. The set will operate, if near a broadcasting station, but will not operate a Loud-speaker.

II. *A Selective Crystal Receiver.* A selective crystal receiver is shown in Fig. 5. With a set of this type, one is capable of hearing stations as far as is



A Selective Crystal Receiver

FIG. 5



SIMPLEST AUDION CIRCUIT

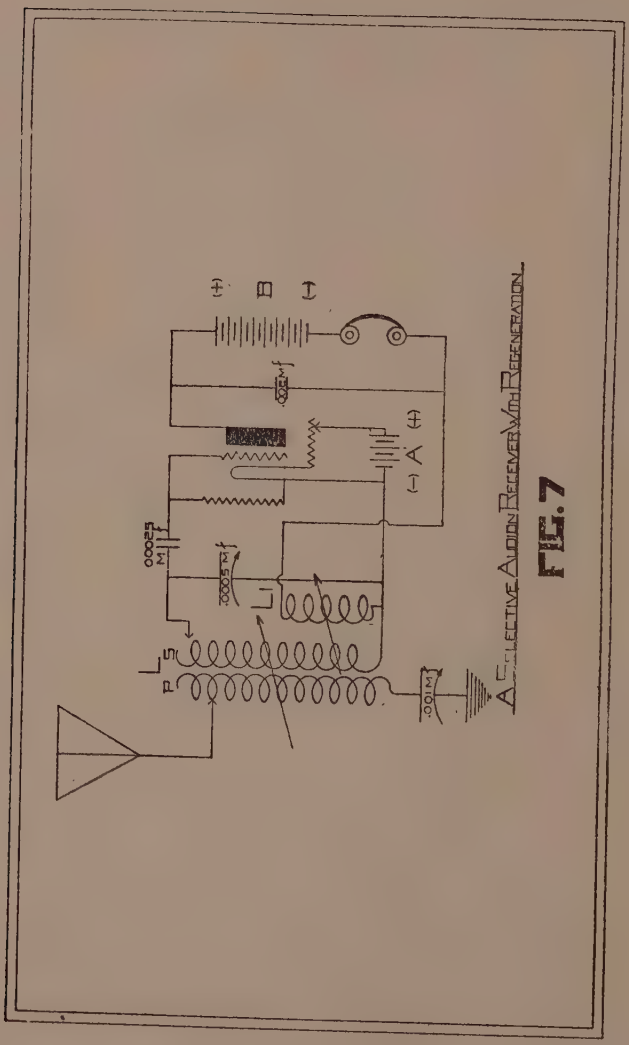
FIG. 6

possible with any crystal receiver. The range depends upon the sensitivity of the crystal, the location of the antenna, and the skill of the operator. For average broadcasting reception, the range will be about ten miles. The variable inductance "L" may be a standard loose coupler or "variocoupler".

III. *Simplest Audion Circuit.* In Fig. 6 is depicted the connection diagram for the simplest receiving set for radio telegraph and telephone with which it is possible to obtain results, using an audion. The voltage drop across the inductance "L" (which may be a two-slide tuning coil) is fed into the input terminals of the audion "V. T." The fixed condenser "C′ " (Capacity .00025 Mf.) and the resistance "R′ " (2 Megohms) help in the operation of the audion. The filament "F" of the "V. T." is fed from a battery "A" and its temperature is adjusted by the ten ohm rheostat "R". The "B" battery, which is in series with the headphones and the plate of the audion, should be variable from 16 to 22-1/2 volts. The set as a whole is adjusted to hear signals by varying "L" and adjusting the condenser "C2".

This set will be acceptable for use up to 50 miles. It is not selective and can be interfered with to a great extent.

IV. *A Selective Audion Receiver with Regeneration.* This circuit (shown in Fig. 7) is essentially the same as Fig. 6, with regeneration added. The antenna circuit is now not directly connected to the audion circuit, but excites the latter by induction. While this method is slightly more difficult to tune, it presents the great advantage that it will tune out interfering stations to a surprising degree, and anyone using this circuit with a single vacuum tube will be able to attain the greatest range possible with the



A Selective Audion Receiver With Regeneration

FIG. 7

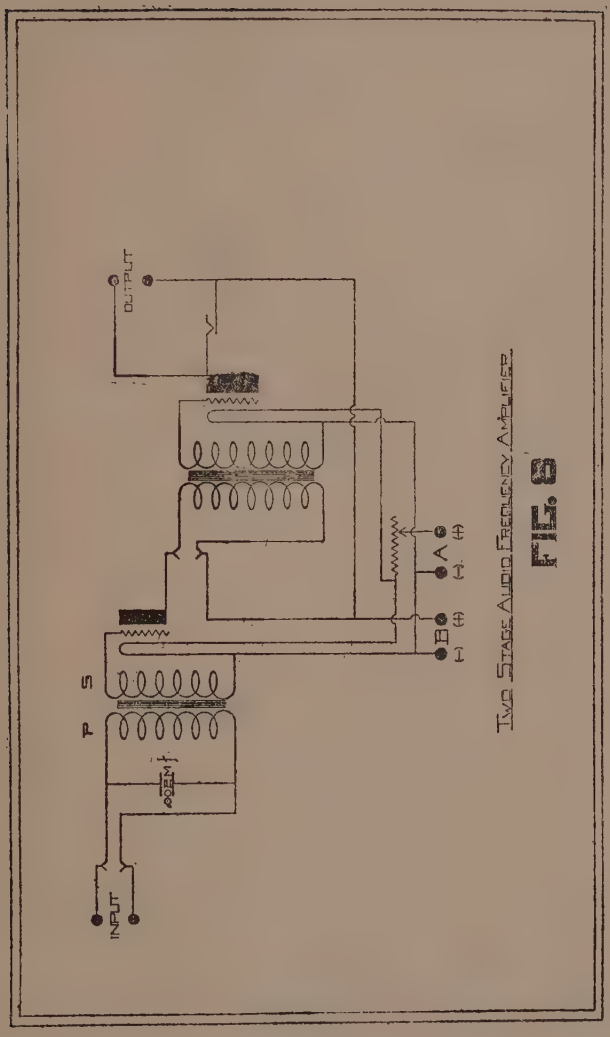


FIG. 8

TWO STAGE AUDIO FREQUENCY AMPLIFIER

tube. The circuit should receive, with an overhead antenna, broadcasting stations up to a distance of several hundred miles in daytime and perhaps several thousand at night. For Loud-speaker operation a two-stage audio frequency amplifier may be placed in the circuit after the broadcasting has been tuned in on the single tube with the headphones. The condenser and leak, "A" and "B" batteries, etc., are all the same as indicated in Fig. 6. Care should always be taken, especially in a set employing regeneration, to see that the rotary plates of all variable condensers are connected to the grounded side of the apparatus.

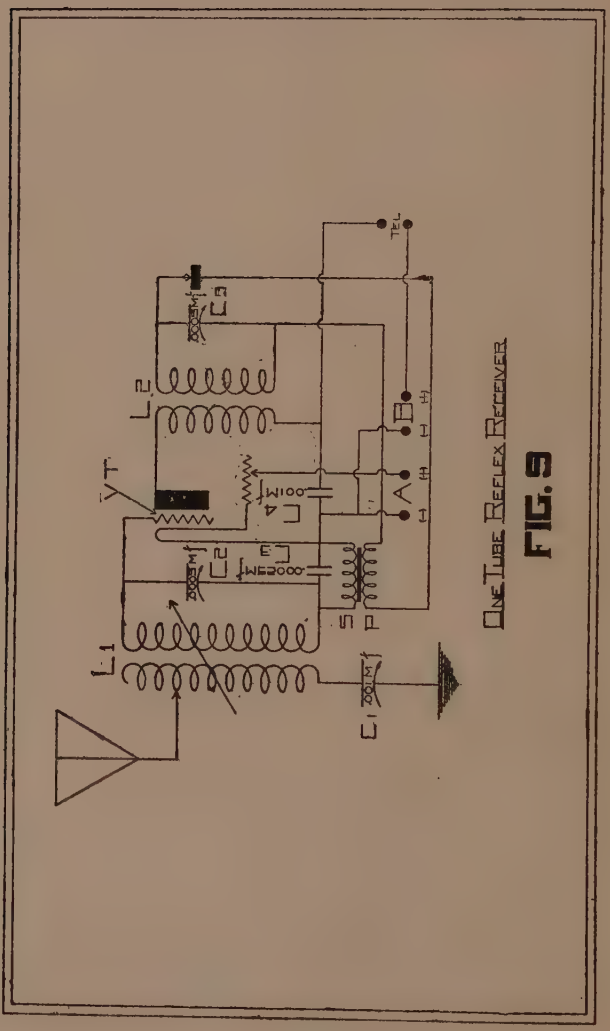
V. *A Two-Stage Audio Frequency Amplifier.* Fig. 8 shows the connection diagram of a two-stage audio frequency amplifier employing low ratio step up transformers and a common rheostat in the filament circuit of both audions. Special care should be taken in the selection of the material used in this piece of apparatus, for, working as it does at audio frequency alternations, it is more than likely to distort the received signal. A transformer with a turns ratio as high as 5 may be employed on the first stage but on the second it is best not to exceed 3 or 3-1/2. The transformers should be impregnated with some good moisture-proofing compound and every effort made to see that all dampness is excluded from the cabinet in which they are placed. The filament rheostat had better have an "OFF" position, or a filament switch should be inserted in series with it for the purpose of conserving the battery when the set is not in use. The resistance of the rheostat used will be about ten ohms for two tubes of the UV-201A type. The reader will note that three jacks are provided, for the purpose of plugging in on the detector tube alone, or the first or second "stage" of the amplifier. The jacks for the detector and first stage may consist of the

two pole, double throw variety, and for the second stage, a two pole, single throw. The "A" battery, for lighting the filaments of the amplifier tubes, may be the same as used for the detector, if it is of sufficient capacity. As for the "B" battery, for the plates of the audions, it may consist of the detector battery in series with one other 22-1/2 volt block section. In this case no negative "B" battery connection to the amplifier will be necessary. The bypass condenser across the primary of the first amplifying transformer is an aid to oscillations in some sets, where when using one tube only, the capacity across the telephone cords is a sufficient bypass, but upon being connected to a cascade amplifier will not oscillate on account of the high impedance in the transformer winding. Little distortion should result, if, in making the amplifier, the builder places the two transformers as far apart as possible and places their iron cores at right angles to each other. If some distortion still persists, it may sometimes be cured by placing a variable high resistance unit across the secondary of one of the transformers.

If the amplifier does not work properly or emits a shrill squeal, one or more of the following defects may be found the cause of such squealing:

1. *Wrong connections on batteries or transformers.*
2. *Batteries of improper voltage or dead batteries.*
3. *Defective tubes.*
4. *Burned out transformer or transformers too close to each other.*

Warning.—Do not use more than 45 volts plate voltage on two stage audio frequency amplifiers in the Philippine Islands. You will not get very much more



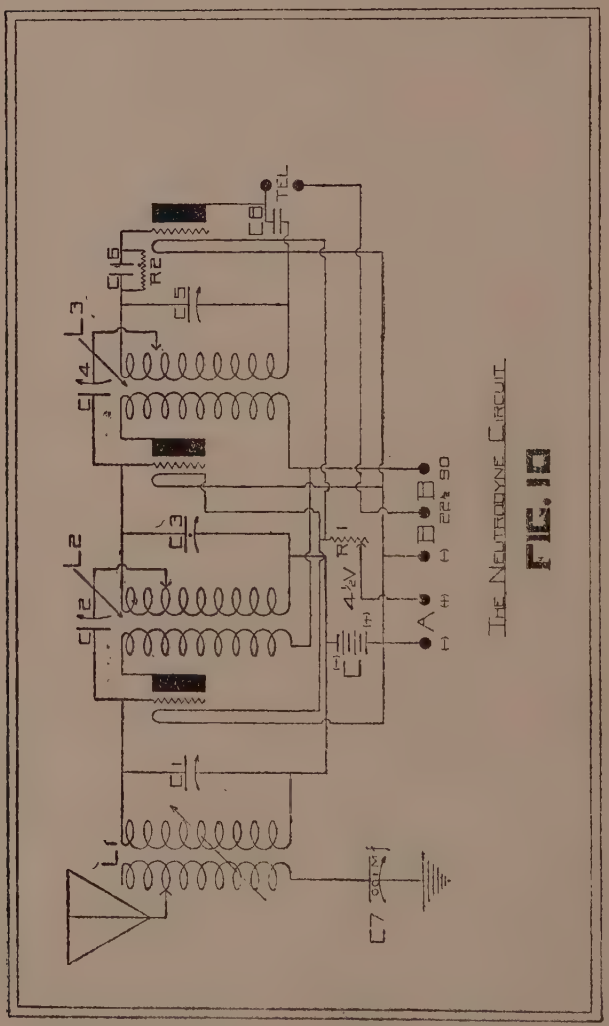
ONE TUBE REFLEX RECEIVER

FIG. 9

amplification by doing so, you will probably get a great deal of distortion, and you are sure to burn out your transformers.

VI. *A One-Tube Reflex Receiver Employing Crystal Detection.* The chief advantage of the "Reflex" receiver is, as has been already outlined, the fact that a few tubes take the place of several. For example, in the circuit here depicted we will find, upon examination, that we are saving the expense of another tube, for the audion "V. T." takes the place of both a radio frequency and an audio frequency amplifier. The constructor will find that a set of this kind will give Loud-speaker operation from local stations, and if more audio frequency amplification is added, more volume will be obtained. The use of a crystal for detection insures clear reception and pure tonal quality. Care should be taken to see that a good crystal is obtained as this is one of the most essential points. The transformers "L1" and "L2" may be ordinary variocouplers. The tube "V. T." may be of the UV-201A type. The audio frequency amplifying transformer had better be of a rather low ratio. The condensers "C3" and "C4" had best be mica insulated and tests should be made to see that they are not short-circuited. The condenser "C1" can be dispensed with, but is necessary for close tuning. If desirable, a bypass condenser of about .001 Mf. capacity may be connected across the primary terminals of the audio frequency transformer "SP".

VII. *The Neutrodyne Circuit.* Figure 10 shows the connections for a three-tube Neutrodyne receiver embodying two stages of short wave tuned radio frequency amplification and an audion detector. The primary tuning condenser "C7" should be of .001 Mf. Capacity, and may be dispensed with when the prim-



THE NEUTRODYNE CIRCUIT

FIG. 19

ary of "L1" is not to cover a wide band of wavelengths. In this case, see that the size of the primary is such as to allow reception of the stations desired. The neutralizing condensers "C2" and "C4" may be made of two pieces of insulated No. 14 wire with their ends about a quarter of an inch apart, and covered by a movable metal cylindrical shell about one inch in length. Once set, these condensers need not be changed until the tubes are changed. The Inductances "L2" and "L3" need not be tapped if they are already set to cover the wavelength band desired. The variable capacities "C1", "C3" and "C5" should be .0005 Mf. "C6" should be .00025 Mf. and "C8" should be .001 Mf. A "C" battery of 4-1/2 volts, connected as shown, should be provided to lessen the "B" battery drain. Adjustments are normally made with "C1", "C3", and "C5". A filament switch may be provided. The grid leak resistance should be of the order of 2 Megohms. If an audio frequency amplifier is connected to the posts marked "TEL" in the diagram, a Loud-speaker may be operated from a loop antenna with satisfactory results.

VIII. *A Short Wave Receiver.* Figure 11 depicts the connections for a short wave receiver suitable for broadcast and amateur reception on wavelengths from 63 to 227 meters. "L1", the antenna coil, wound as shown in Fig. 11(a), is of 5 turns and 2-1/2" in diameter. "L2", the first section of the secondary, is six turns of No. 16 D. C. C. wire, wound as shown in Fig. 11(b).

NOTE.—"L1" and "L2" are coupled to each other.
"L3" is the same as "L2", but is of 12 turns.
"L4" is the secondary loading coil. Thirty turns, same as "L2" and "L3".
"L5" the tickler coil, is eleven turns of No. 28 D. C. C.

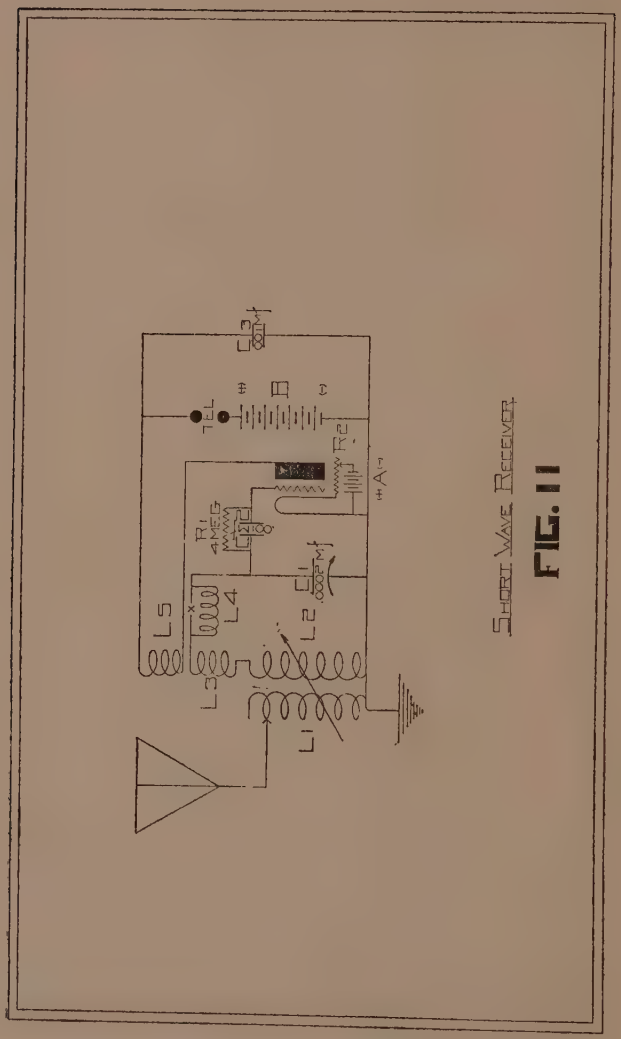


FIG. 11

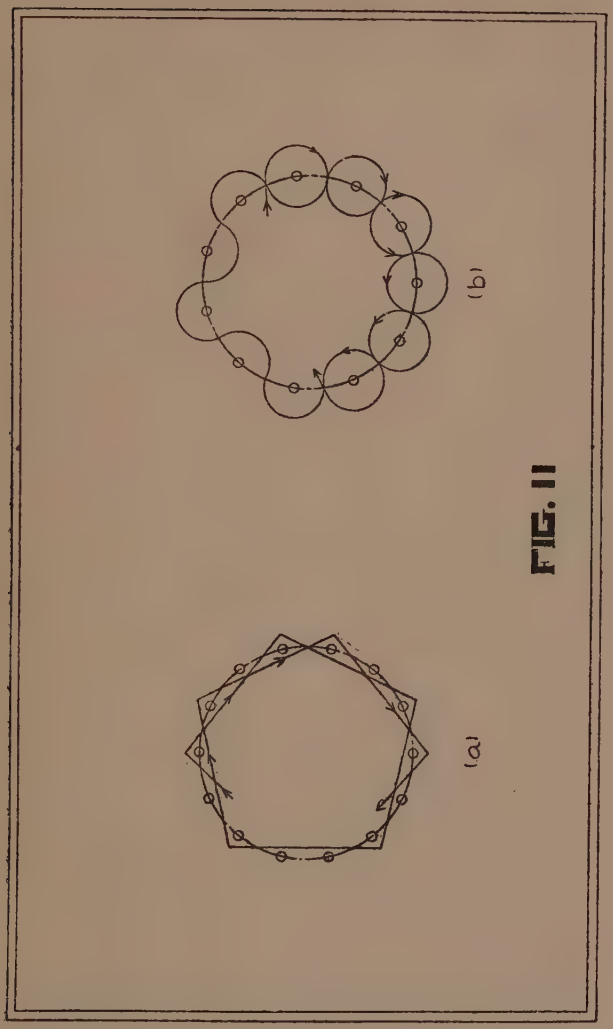


FIG. 11

NOTE.—"L3" and "L5" are coupled to each other. The capacity of the condensers is shown in the figure, as is also the grid leak resistance.

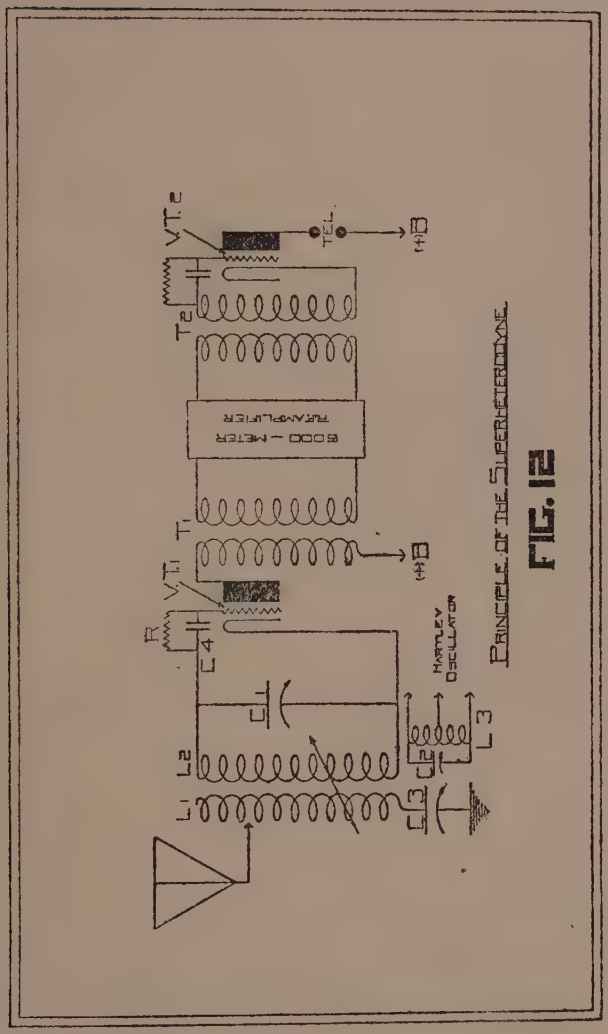
NOTE.—Do not use any taps on this set. They cause losses. The same suggestion holds true as to "molded-mud" and fibre insulated condensers and audion sockets. *Only the best are suitable here.*

"L1" and "L2" should be widely separated from "L3" and "L5". A tube of the UV-201A type may be used. Amplification (audio frequency) may be added at the posts marked "TEL".

The experimenter, when making this set, should first mount it on an ordinary board, where all parts are readily accessible. (The "Breadboard" style).*

IX. *The Super Heterodyne Principle.* Figure 12 shows the schematic connection diagram of a super heterodyne receiver. It is not necessary in a volume of this scope to present the wiring diagram in detail. The following is the theoretical operation of the super heterodyne principle, which is, after all, quite simple: The primary, "L1", is adjusted to "fit" the antenna or loop used, to the set. The tuning is then done with condensers "C1" and "C2". "C1" controls the wavelength of the first detector circuit. "C2" controls the wavelength (frequency of oscillations) of the local oscillator. This may be an oscillator of the "Hartley" type. The condensers "C1" and "C2" are set so as to tune the two circuits a few cycles apart. The oscillations produced by the incoming signal in the first detector circuit clash with those set up in the local oscillator circuit, and a "beat" frequency is produced (that is, a frequency that is equal to the

* I am indebted for the above information to the editors of "QST". For fuller details on short wave sets of this type see "QST" for February, 1924, Page 8.



PRINCIPLE OF THE SUPERHETERODYNE

FIG. 12

difference of the first detector frequency and the oscillator frequency). This "beat" frequency is always made exactly equal to the frequency at which the long wave radio frequency amplifier (see Fig. 12) works best. This is usually six thousand meters (50 kilocycles). *Thus by changing the wavelength of the incoming signals they are amplified to a much greater extent than if they were not so changed.* This is the principle upon which the Super-heterodyne's success is based. The signals, after passing thru the long wave amplifier, are detected by "VT-2" and may be heard in a pair of phones, or amplified, as desired.

Those who have read the foregoing may still wonder why other sets employing radio frequency amplification do not operate with as high a degree of efficiency as the Super-heterodyne does. The explanation is simple: Transformers cannot be designed to efficiently amplify radio frequency oscillations of very high frequency (low wavelength) when using the American audion tubes now on the market. They can, however, be constructed to amplify very efficiently, with the same tubes, the lower frequencies (higher wavelengths) and so inasmuch as this is just what they do in the Super-heterodyne, great efficiency results.

Referring to Fig. 12:
"C3"-.001 Mf.
"C1" & "C2"-.0005 Mf.
"C4"-.00025 Mf.
"R1"-2 Megohms.
"L1" and "L2" may be an ordinary variocoupler or may be replaced by a loop antenna. The "Hartley" oscillator must be coupled to "L2". As loose coupling as possible should be used. "T1" and "T2" are radio frequency coupling transformers.

NOTE.—Construction of this set should not be attempted by one who has not had considerable experience in receiver construction.

Due to the severe static prevailing, at times, in the North and South of the Philippine Archipelago and other interference experienced in the Central portion of same, a range of only half that usually attained in the United States with a certain type of receiver may be expected. Thus, if a receiver is advertised in the United States as having a range of 3,000 miles, the owner of such a set in the Philippine Islands should only expect a range of 1,500 miles from it. Frequently the range will be even less than this.

CHAPTER II

PRINCIPLES OF RADIO PROPAGATION

Everyone knows that when certain objects are hit or twanged a musical hum will be set up. The Snare drum and Banjo string are familiar examples. Often the eye can detect a movement in the object affected. If some means are employed to measure the speed, or frequency, of the vibrations ("Alternations") of this object, it will be found that they seldom exceed one thousand per second. One alternation is one complete movement up and down, or back and forth, as the case may be. If the number of alternations per second greatly exceeds one thousand, the human ear will have difficulty in hearing same. You are doubtless familiar with the high-pitched note produced by some insects, notably crickets, which at times is so shrill as to be almost inaudible. A point still higher than this is reached where the diaphragm of the human ear will no longer respond to these sounds of high alternation, and when this point is reached we may say we have arrived at the higher (wavelength) limits of radio frequency vibrations.

Radio instruments all employ electricity and, in electrical circles, it is common to speak of these alternations as "cycles" altho the term is interchangeable.

Now, it has been proven that radio waves, as well as light waves, all travel at a speed of 186,300 miles per second. Changing this to the more standard form of meters, we obtain 300,000,000. The use of this number will be shown later.

A Receiving Installation

While the analogy is not very exact, let us look at Fig. 13.

The Line AB in (a) represents a bow string at rest. If left alone it will not set up alternations. However, if plucked at its mid point it will begin regular alternations from ACB to ADB and thus will disturb the air particles immediately surrounding it, with a result that sound waves are set up and can be heard by the human ear.

The electric current ADB, in (b), will not, if flowing in one direction at a speed of 300,000,000 meters per second, (direct current) set up disturbances in the ether (an undefinable material permeating all space and capable of conducting radio frequency alternations). However if it is made to periodically change direction, it will take the form ACDEB [Fig. 13(b)], the "current" still flowing at the same speed. The "alternating current" ACDEB will now set up vibrations in the ether. These vibrations will travel in every direction from the conducting material through which they are flowing. These electrical vibrations are similar to the vibration of the bow string, but as they travel thru a different medium and alternate much more rapidly, the human ear cannot detect them.

Some means must be employed to pick up these electric vibrations and change them to a frequency audible to the human ear. How shall this be accomplished?

Let us see just what form these electrical waves take as they pass thru the ether:

Figure 14 depicts wave forms of the two different types of transmitters in use at this time. Both curves (called "sinusoidal" curves) are greatly exaggerated

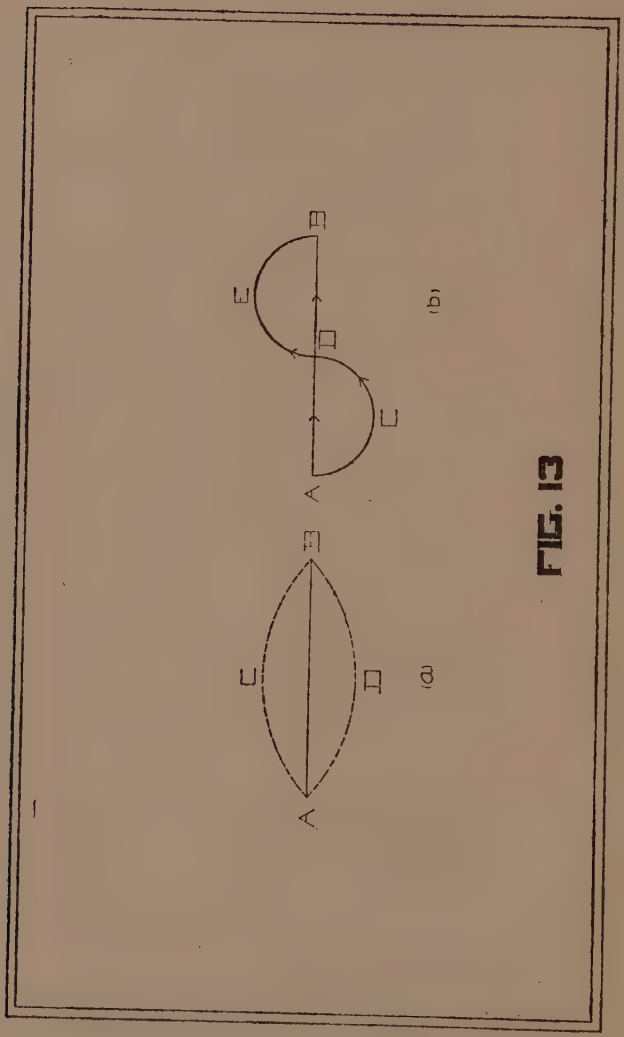


FIG. 13

WAVE FORMS

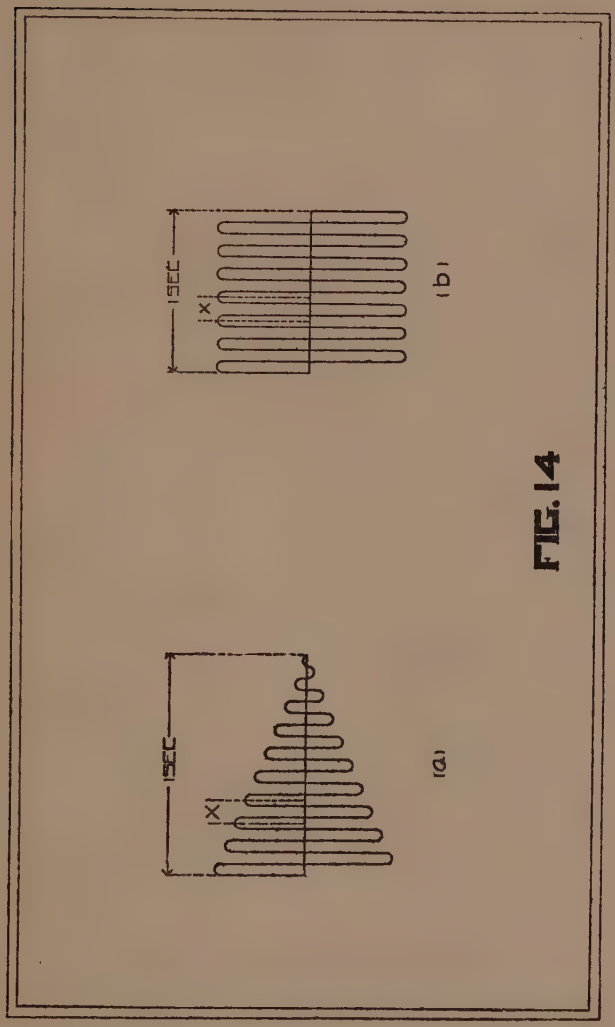


FIG. 14

TYPES OF RADIO WAVES

for the purpose of ready portrayal. In Fig. 14(a), we have the wave form of a "damped" wave transmitter; so termed because it sends out spurts of power at regular intervals, each spurt (called a "wave train") gradually dying out (or being "damped") and being succeeded by another spurt. This is the wave form emitted by all types of "spark" transmitters, (those employing discharges of electrical sparks) and is now considered archaic, if not obsolete.

The sketch [Fig. 14(b)] depicts the wave form of an "Undamped" wave transmitter (so called because its wave is continuous or sustained.) This type of wave is the more modern of the two types and is generated by transmitters using one of the three devices following:

1. *The High Frequency Alternator.*
2. *The Poulsen Arc.*
3. *The Oscillating Audion.*

The high frequency alternator is simply an alternating current generator of high peripheral velocity. Revolving at this high speed (20,000 R. P. M.) it thus generates alternating currents of radio frequency, which may be led into a suitable radiating system and "broad-casted" into space. This system is very expensive due to the precise machining necessary, and is used only for high power installations.

The *Poulsen Arc* (named after the Danish inventor Valdemar Poulsen) has as its base the electric arc. This is produced between copper and carbon electrodes in a sealed chamber filled with gas, and may be likened to the familiar arc used in motion picture projectors. This arc is capable of setting up sustained oscillations in a radiating system and does so rather cheaply, as compared with the alternator system.

The third system, the *Oscillating Audion,* is perhaps the best for all around use of the three. Vacuum tubes are now built in sizes ranging from five watts to one hundred thousand watts and thus find application in all sizes of radio transmitters. They are similar to the audions used in receiving, but have more provision for high voltages and cooling.

The Undamped wave and Damped wave have a few points in common that will be of interest: They both travel thru space at exactly the same speed. (300,000,000 meters a second). The wavelength of both is measured by the distance between succeeding crests of the same wave in meters, as in "x" Fig. 14(a). It is obvious that if this distance of one alternation from another is divided into the total distance traveled by the wave in one second (300,000,000 meters) the result will be the total number of alternations per second. This holds true for both types of wave forms.

Let us solve some examples having to do with this relation: 1. If a sending set operates at 1/2 meter wavelength, what will be the frequency of the oscillations it sets up in the ether?

Ans: $\dfrac{300{,}000{,}000}{\frac{1}{2}} = 600{,}000{,}000$ cycles per second.

2. If this sets wavelength is raised to 200 meters, what is the frequency?

Ans: $\dfrac{300{,}000{,}000}{200}$ or one million, five hundred thousand cycles per second.

3. I have a Navy standard wavemeter which is calibrated in kilocycles, from 100 to 3,000. What is the wavelength range of my wavemeter in meters?

Ans: A "kilocycle" (abbreviated "kc") is one thousand cycles. Evidently your wavemeter has a range of 100,000 cycles to 3,000,000 cycles. This would be equivalent to a wavelength range in meters of

$$\frac{300{,}000{,}000}{100{,}000} = 3{,}000 \text{ meters to}$$

$$\frac{300{,}000{,}000}{3{,}000{,}000} = 100 \text{ meters,}$$

or One hundred to Three thousand meters.

Now we will take up the principal advantages and disadvantages of, and compare the damped and undamped methods of ether disturbances.

A Damped wave, or spark transmitter has the following advantages: Low price: the average price for a spark set is considerably less than the price of an audion transmitter of equivalent power. "Broad" Wave: A spark set can be heard on many waves other than the one to which it is tuned. This is both an advantage and a disadvantage. It is of advantage when communication must be established quickly, as in calls for help at sea, but it is a disadvantage for ordinary use, as the proclivity to interfere does not permit several stations operating in the vicinity of each other.

Other Disadvantages of the Damped Wave.— Shorter distance for equal power: Watt for watt, the damped wave transmitter will not cover the same distance as does the undamped. It is harder to read thru interference especially at a distance.

Advantages of Undamped Wave Transmission.— The undamped wave transmitter will give greater range for the same power, will not interfere nearly as much, and permits operation of more stations on

nearby wavelengths than does the damped wave transmitter. It also permits the use of Radio Telephony.

Disadvantages of Undamped Wave Transmitters.— High cost, and, in cases of distress calls, is harder to pick up quickly.

These two forms of transmission are now used through all hours of the day and night. How can we pick them up? You say, with a receiving set. Yes, but why is it that we can hear these ether disturbances with a receiving set? What quality do receiving sets possess that our ears do not?

Simply this: that they will respond to electromagnetic waves only, while our ears will respond to sound waves only. We already have a device for converting electrical waves into sound, that is, the telephone receiver: consisting of a thin sheet of metal, called the "diaphragm", suspended over an electro-magnet, which moves and makes sound waves when electric current passes thru this electromagnet. But if we try to hear radio signals with this receiver alone we will be disappointed.

Turn to Fig. 4, in Chapter I, and see the simplest form of receiver for radio. Of what does it consist besides our old friend the telephone receiver? Why, of a device called an antenna for picking up the ethereal waves, and a piece of mineral called a "crystal detector". The antenna is evidently nothing more than a piece of wire suspended in an elevated position, so it must be the crystal detector that performs the work. All right; now let us look again at Fig. 14. Do you see how the electric current is continually changing its direction? For every curve above the line, there is another curve below it. Now we have the reason why our simple telephone receiver will not

allow us to hear the radio waves. The electrical flow goes through the coils of wire in the telephone receivers in one direction, but, before the diaphragm has had a chance to move in this direction, all the current flows back again, neutralizing the effect of the previous "push". Thus it goes, each succeeding half wave neutralizing the effect of the preceding one, and so the diaphragm is forced to remain stationary.

Obviously, what is needed is a device that will let the current go thru one way, but will not let it come back again. The Crystal detector does this and acts in much the same way as does the valve in the tire of our automobile or bicycle when air is being pumped in. All devices which possess this quality are called "rectifiers". The audion is a much better rectifier than is the crystal, that is, it is much more sensitive. We shall discuss it more in detail later on.

The crystal detector will "detect" only the type of wave shown in Fig. 14(a), that is, the damped wave. "Oh, no!" you say, "it must detect the other also, for you have just told us that an undamped wave is essential to radio-telephony, and we know that we can hear the radio telephone over our crystal set." True enough, an undamped wave transmitter *is* essential to radio-telephony, but it is not the undamped wave component that you hear, but a damped wave superimposed on the undamped "Carrier-wave" at the broadcasting station. It is this damped wave, called the "Modulation", that you hear, after the Undamped wave has delivered it, figuratively speaking, to the doorsill of your receiver.

The reason a crystal receiver cannot pick up undamped waves may be more easily learned by reference to Fig. 14(b). Here all the waves are just the

same height above the line. But the damped waves [Fig. 14(a)] rise higher and higher and then die out just as the waves in the ocean do. New waves keep forming all the time and each separate wave makes a little tick in the telephone receivers. Upon the number of these waves per second depends the pitch of the sound wave we hear in the telephones. The Undamped waves [Fig. 14(b)] always remain at the same level with respect to one another and never die out while the transmitter is operating. A method of reception for this type of wave will be better understood after the action of the audion has been explained.

More often than we would desire, we hear the term "interference" used in connection with radio. Interference exists when a receiving operator has difficulty in hearing a transmitting station due to louder signals (from some other station) or noise, coming thru his receiver. This falls into two classes: Natural interference and Radio interference.

Natural Interference.—When two cloud banks of opposite polarity meet, there takes place what we call "Lightning". This is called by radio operators, among other things, "static". In certain parts of the world, as around the Equator, static persists thruout the entire year, and the operator's life is filled with misery, who tries to receive thru it. It is a low rough scratching or popping sound, and will not persist if the antenna is disconnected from the receiver, as will noises arising from defects in the set itself.

Other forms of interference of like nature are found in the sparking of electric motors, violet and X-ray machines, and in discharges on a high voltage electric feeder line. Other noises may come from

poor connections or dead batteries in one's own receiving set.

Radio Interference.—Radio interference is due to one or both of two things. The transmitter may be of a type that emits a "broad" wave (as a spark set) or it may be badly adjusted, which amounts to the same thing; or the receiver may be badly adjusted. In general, if, after the receiving operator has attained the best adjustments possible with his receiver and the radio interference still persists, it may, usually, be eliminated by having the antenna-ground circuit disconnected entirely from the audion circuit, and "loosening" the coupling between them. (i. e., placing the primary and secondary coils at a distance from each other.) This will make closer adjustment of the receiver necessary, but will lessen the interference to quite an extent.

CHAPTER III

ANTENNAE AND THEIR CONSTRUCTION

In the last two chapters we have discussed apparatus for the reception of radio waves, and, in a general way, apparatus for their transmission. In these chapters reference has been made to "antennae", "loops", and "radiating systems". While we know that all this means different forms of structures for picking up sufficient energy to work the receiving apparatus, or putting out the power of the transmitter into the air, we have no detailed knowledge as yet of the form these different structures take.

Let us look at Fig. 15:

"A" may represent a transmitting station. "2" will be the source of radio frequency power, and "1" the antenna. "B" may represent the receiving station. In this case "2" represents tuning apparatus and instruments for the conversion of the radio frequency waves into waves of audible frequency, i. e., sound waves. Both "A" and "B" are directly connected by a common bond, the earth. It is the purpose of this chapter to show the different types of structures that may be used at "1", and the different forms of earth connections.

First, however, let us see how the energy is radiated in the case of "A". If the station is adjusted correctly, half of its energy will leave "2" at the earth connection, and half at the antenna "1". We must not think, however, that all this energy goes to the work of propagating radio waves. Some part of it is first spent in counteracting the "resistance" of the

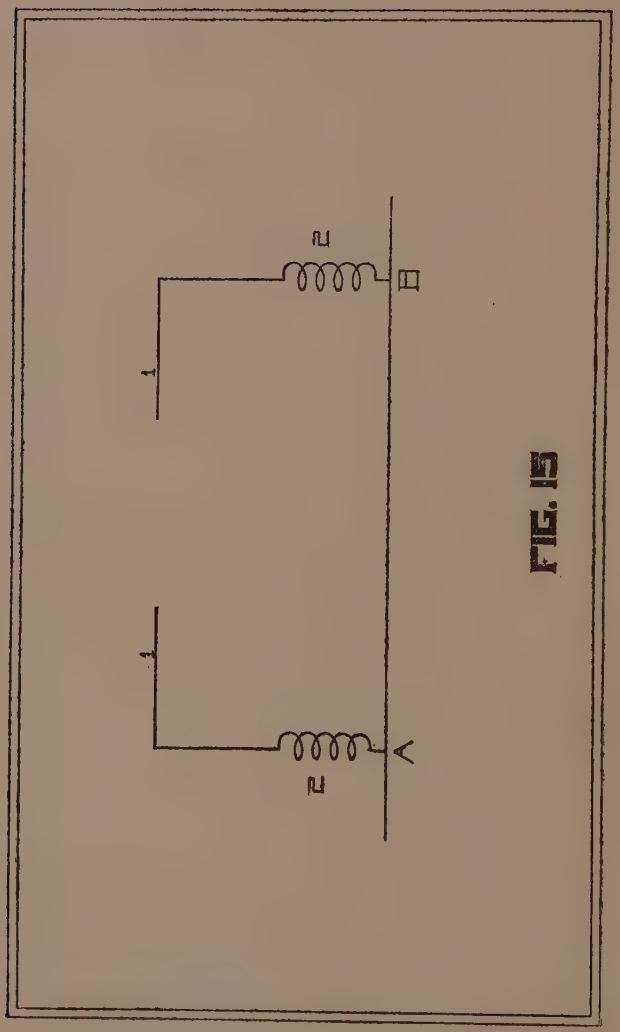


FIG. 15

ANTENNA CONSTRUCTION

antenna conductors and in the resistance of the earth itself. This will make an equivalent circuit to Fig. 16, as follows:

"Rx" and "Ry" are here the effective resistances offered by the antenna and ground respectively, at the frequency used.

Again, in the case of an antenna situated as in Fig. 17, we have other losses known as "reradiation", or "harmonics".

In this case "T" is the operating house in which the apparatus is situated. "P" & "P" are iron pipe masts. "GW" & "GW" are steel guy wires for the purpose of strengthening the masts. We now see that part of the energy that finally reaches the antenna "1" after overcoming the resistances of antenna and ground, will be grounded thru the conductors "P" & "GW", which will then act as antennas in themselves, and radiate power on a different wave from the antenna "1". Obviously this energy on another wave will not help any, and the operator at the receiving station can listen on only one wave at one time, so we must count the power absorbed by "P" & "GW" as energy *lost.* Also if trees, buildings, metal structures and a multiplicity of guy wires are present, much energy will be lost thru them as well. The energy "lost" and the energy radiated are usually denoted by resistances, *the energy radiated being called the "radiation resistance".*

ANTENNAS FOR RECEIVING SETS

Owners of broadcast receivers which require outside antennas will find the structure depicted in Fig. 18 of value:

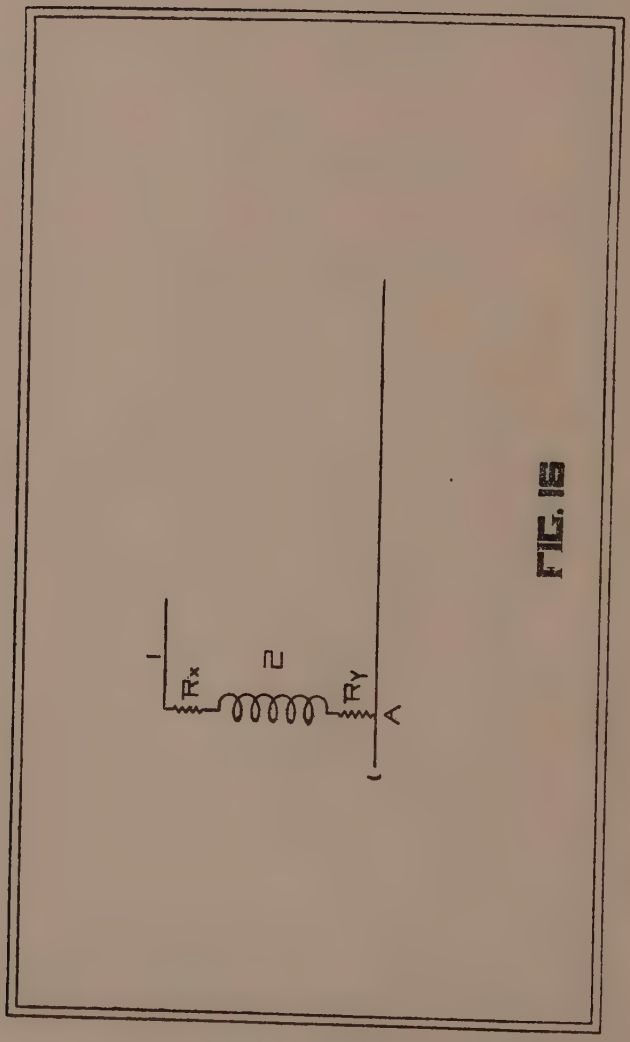


FIG. 18

ANTENNA LOSSES

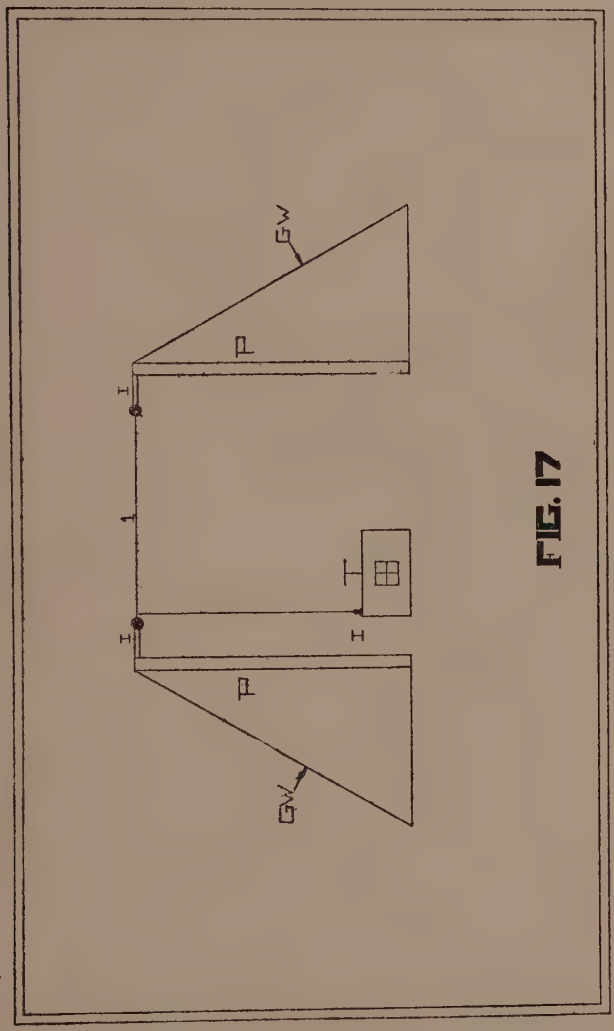


FIG. 17

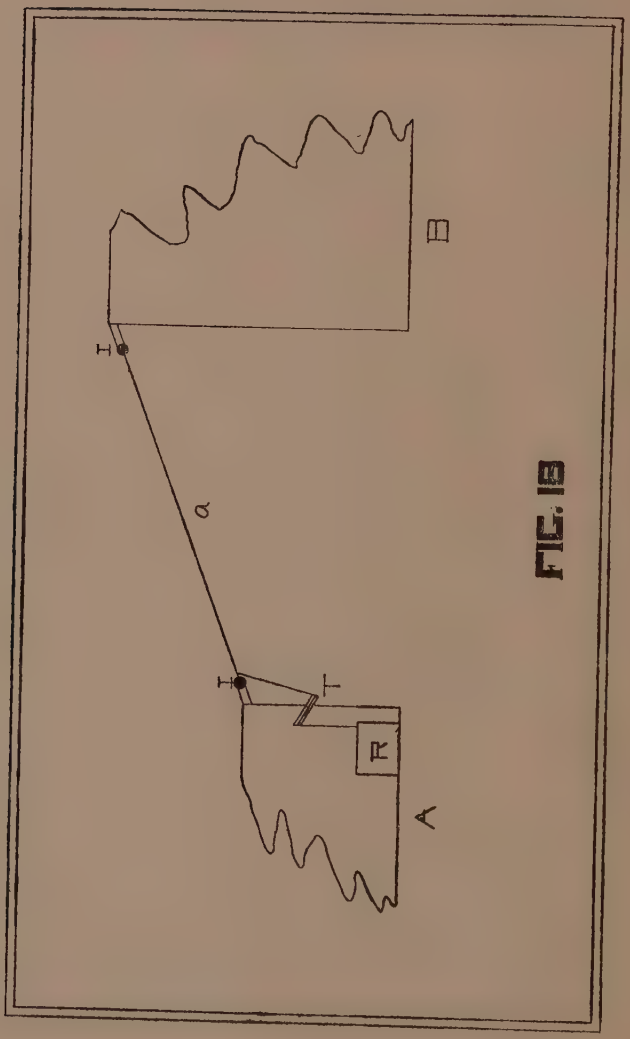


FIG. 18

ANTENNA FOR RECEIVERS

This antenna consists of a single piece of hard drawn copper wire, No. 12 gauge and enameled, if possible. The insulators "I" should be several inches in length, ribbed, and constructed of glass, glazed porcelain, electrose, or some other similar approved material. "T" is the "lead-in bushing" and serves to insulate the antenna from the building. "R" is the receiving set. It should always be located at the lower end of the antenna. The total length of wire from the receiver to the farther insulator should not greatly exceed 200 feet. A short antenna adduces selectivity. Of course other materials and sizes will do, but the operator who wants the best results will do well to follow the specifications given here. If the antenna is very short, placing several wires in multiple with it will not increase its effective wavelength range. All joints should be firmly spliced and *soldered* to protect them from corrosion. If the constructor uses a little care, he will find that it is not necessary to make any joints in the system just described. At all times keep the antenna wire several inches from anything else, especially conducting materials. It does not particularly matter whether the wire has a coating of insulating cloth upon it; the only difference being the weight this coating adds to the system. When using a tree for a support, see that the wire ends several feet from the nearest branches, the remaining distance being made up of rope. When fastening the wire to the tree, always make ample provision for the swaying caused by the wind. If bamboo supports are used, take care to see that they are well guyed, as they always sway in the wind and are inclined to break if too much strain is placed upon them. Iron pipe makes a very good an-

tenna support but is very heavy and, being a conductor, absorbs a large portion of the current put into the antenna, besides being rather costly. The best all around support from a standpoint of price and electrical efficiency is some form of a wooden mast or tower.

Do not place the antenna where it is in danger of touching electric power wires. Experimenters have been electrocuted in just this fashion. At the same time be cautioned against climbing supports that are designed to uphold a fraction of your weight. They may not break the first few times, but sooner or later, they will.

THE LOOP ANTENNA.

Figure 19 is a schematic drawing of a typical loop antenna. The wire is wound on a quadrangular insulated frame, in such a fashion as to insulate each turn from the others. The two ends of the coil "A" & "B" are brought to binding posts on the base of the structure, whence they may be led to the proper parts of the receiver. The box-like frame is mounted on the base by a pivot and is free to turn in any plane direction. It will be found that maximum signal intensity results when the plane of the loop is approximately parallel with that of the broadcasting station. The loop becomes more effective as its size is increased, i. e., as it more nearly approximates the dimensions of an "overhead" antenna.

Late experiments tend to show that the loop proves an efficient directional, non-interfering radiating system when used with an audion transmitter. In this case, the loop is wound with heavy wire or copper tubing, and sending condensers are placed between it and the source of power.

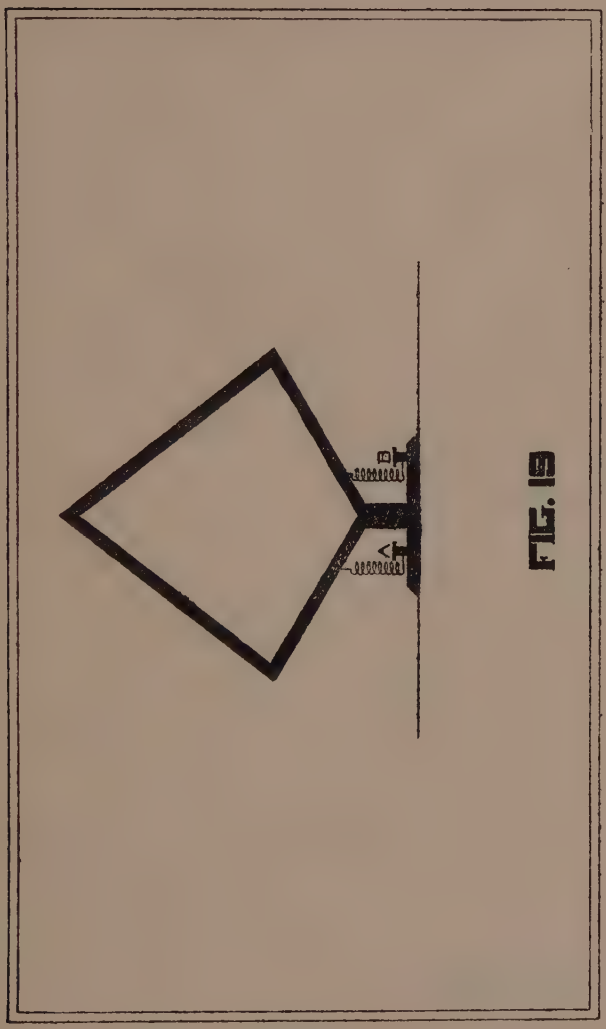


FIG. 19

LOOP ANTENNA

Other Forms of Receiving Antennae may be employed, using the electric light or telephone wires for the antenna, with a suitable condenser in series.

ANTENNAE FOR TRANSMITTERS

GENERAL: The antenna for transmission is essentially the same as the overhead antenna used for reception but, inasmuch as a greater amount of power is handled, greater precaution must be observed against R. F. (Radio Frequency) leakage and resistance. The size of the transmitting antenna need not be greater than that used for receiving; everything in this respect depending upon the wavelength used. Following are given a few practical notes on transmitting antennas:

(A) *Insulators.*—About the best insulator you can use is the glass "pyrex" type. These insulators allow very little of the current to pass thru them and are very strong. Variations of this are plate glass panes for lead-in insulators; glass towel racks; olive bottles, etc. Porcelain insulators are also good if vitrified properly, and run the glass ones a close second. Insulators at least ten inches long should be employed in the average amateur station. If several insulators are used, place them all in series. *Do not* make the fatal mistake of connecting insulators in parallel. Each insulator is equivalent to a resistance. If connecting resistances in parallel lowers the total resistance it follows that connecting insulators in parallel lowers the insulation. Conversely, insulators in series have greater insulation.

(B) *Wire.*—No. 12 solid hard drawn copper is best here. Have it enameled if possible.

(C) *Splices.*—Make them long and see that the solder *sinks in.* A poor splice only adds so much additional resistance to an antenna.

(D) *Guy Wires.*—Use as few as possible and split them up into ten or fifteen-foot sections to keep away from harmonics. Try to keep away from porcelain "egg" insulators. They may be strong mechanically, but their dielectric absorption is usually very high.

THE INVERTED L ANTENNA

The inverted L antenna is very popular among amateurs because it makes use of all the space available. Either a flat top (shown in Fig. 20) or a cage top may be used. The cage top is depicted in Fig. 21. The flat top and cage top have about the same characteristics, all other conditions being equal. If the flat top is kept at about 50 feet in length, the wave of the transmitter will usually not exceed 200 meters. The spreaders should be at least 10 feet in width and six or more wires may be used with good results. The inverted L type of antenna is slightly directional, better results usually being obtained in the direction of the open end.

THE T ANTENNA

Figure 21 depicts the general plan of a T type antenna. A cage top is shown. This may have the same number of wires as the flat top of Fig. 20. Resistance of the whole unit will be considerably lowered if every point of contact between wires is firmly soldered. The T type of antenna is non-directional, that is, stations in its plane have the maximum response obtainable. The length of the flat top should be twice that of the "Inverted L"

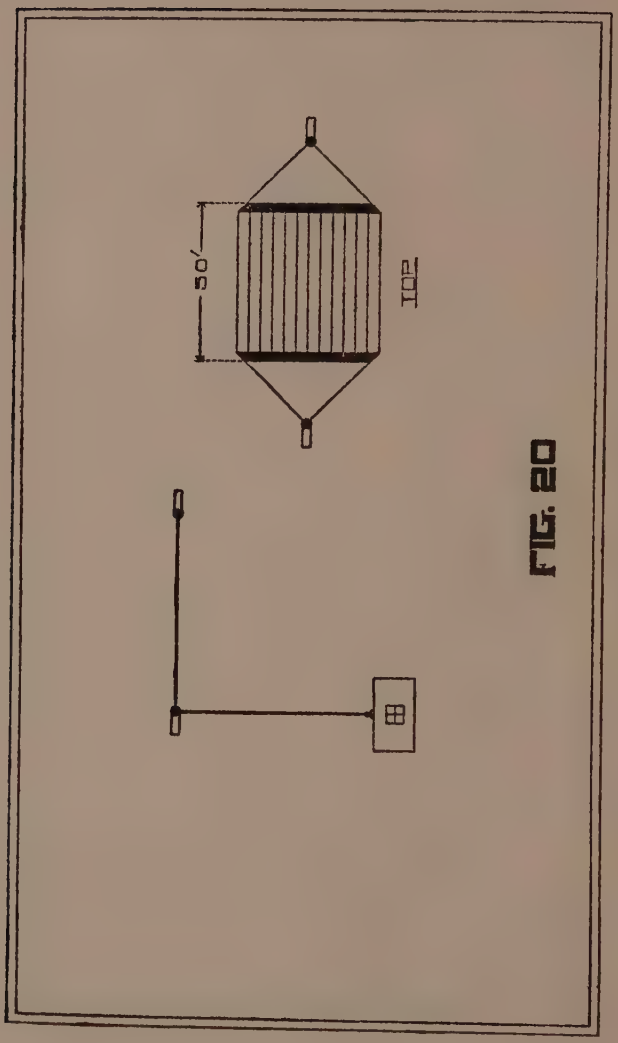


FIG. 20

ANTENNA CONSTRUCTION

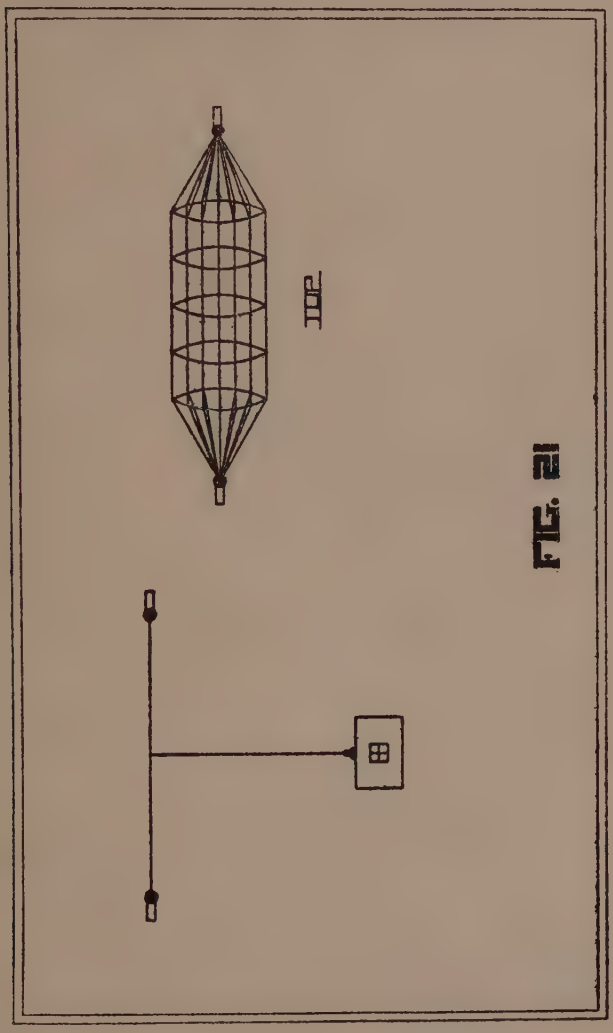


FIG. 21

ANTENNA CONSTRUCTION

type, if other dimensions are the same, to give an equivalent wavelength. Care should be taken while constructing an antenna of this type to see that the lead-in is taken from exactly the midpoint of the top. If this is not done a large portion of the current put into the antenna will be expended in useless harmonics.

Other Types of Antennae are prevalent and are usually constructed as a result of some local condition that prevents the usage of one of the types just outlined. The chief ones follow:

(A) *Triangular.*—Supported by three masts. Used extensively by U. S. Navy for medium and high power installations. Non directional.

(B) *Fan.*—Consists of several wires depending from a conductor suspended between two upright supports. Directional.

(C) *Umbrella.*—Requires single support only. Wires run from top of support to points on a polygon laid out on the earth's surface of which the center is the base of the support. Used extensively by U. S. Army for medium power field installations. Non-Directional.

In erecting an antenna of any kind remember the following rules and you will not go far wrong:

1. *Insulate sufficiently.*
2. *Make good electrical joints.*
3. *Keep away from other large bodies, especially metal ones.*

GROUNDS FOR RECEIVING SETS

We have learned that a connection to the earth's surface is necessary in conjunction with an antenna. We now give a few examples of good "grounds":

First, the direct ground, and second, the capacity ground, or "earth screen".

The Direct Ground.—If the reader lives in a vicinity where water piping is extensively laid, he will do well to find the nearest cold water pipe to his set. Find where this pipe enters the earth, then remove the soil surrounding it to a depth where moist ground is encountered. (This is easy in the Philippines, where a large percentage of the population resides near the ocean, or a river of some sort.) Now secure a ground clamp (a band of copper which may be clamped tightly around the pipe) and scrape the water pipe clean and shiny at the point where the moist ground is encountered. Fasten the ground clamp firmly around the pipe at the clean spot so that no force can move it. Now run a heavy piece of wire on insulators from the receiving set to the ground clamp, and solder the wire to the clamp. If now the earth is replaced in the hole, you will have completed a very efficient ground connection.

Figure 22 shows the wrong way and the right way of attaching a wire to a pipe near a coupling. Always attach the wire to the pipe on the side of the coupling nearest the ground. Gas piping is not suitable for a ground connection.

If one is not situated where water piping is at hand, or is not extensive, the following method may be employed:

Under the antenna dig a pit in the earth until moist ground is encountered. At this point bury as many metal objects, such as boilers, copper sheets, etc., as possible. Solder wires to each of these objects, and connect each wire with solder to a central wire of large size, which wire carry on insulators to

GROUND CONNECTION

the receiving set. Then fill the pit with salt water and re-cover it with earth. This will give, if done properly, a very efficient grounding system.

THE "CAPACITY" GROUND, OR COUNTERPOISE

In case there is no water piping at hand and the soil is unusually dry, so that a direct earth connection of low resistance is impossible, what is termed a "counterpoise" may be employed. For receiving purposes, this counterpoise may consist of a single insulated wire, of the same length as the antenna, stretched out on the ground and insulated therefrom. One end of the wire is connected to the "Ground" binding post of the receiving set and the free end stretched in the same direction as the antenna. If desired, this wire may be supported on insulators several feet above ground; the insulators being similar to those used on the antenna. Or, for maximum results, and for use with a transmitting set, a multiplicity of wires may be employed, all the same length, and all bonded together.

An ideal counterpoise for transmitting (or receiving) is depicted in Figure 23.

In Fig. 23, "I" are insulators, "P" posts for supporting the counterpoise, and "A" the operating house. Note that all the wires are of the same length and are bonded to each other at their ends. All wires run to a central insulator, passing thru the roof of the operating house, and are thence connected to the transmitter. Anyone using this counterpoise either alone, or in combination with a direct "ground" is assured of having the most efficient earth connection possible.

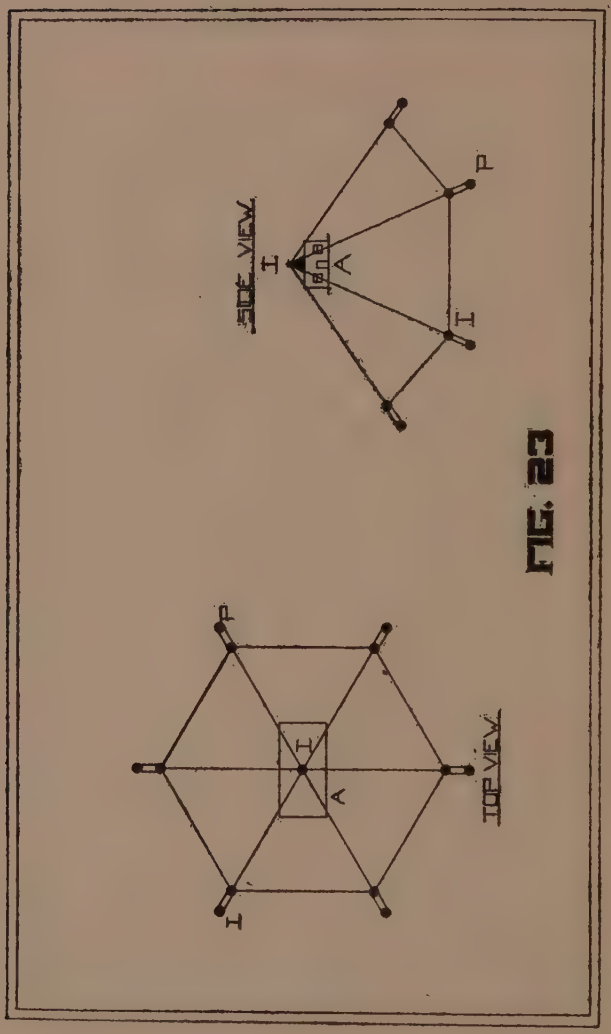


FIG. 23

COUNTERPOISE CONSTRUCTION

NOTE: All the wires in the counterpoise should have the *same length.* The insulation, etc., of the counterpoise is just as important as in the antenna. *Do not expect* efficient operation when using a good antenna with a poor counterpoise or "direct" ground.

CHAPTER IV

SIMPLE TRANSMITTERS

In Chapter II, we discussed the form and manner of the propagation of radio frequency waves. In the foregoing chapter we have shown different forms of structures for disseminating radio frequency current in the ether. Now we will take up methods of manufacturing this radio frequency current and controlling it.

We have already explained two different methods of producing radio frequency oscillations. One of these oscillations was termed "damped" and the other "undamped". We also found that radio frequency oscillations were those of over several thousand alternations per second. (Over 20,000 is the generally accepted quantity.) We will now review these points more in detail in describing the following transmitters:

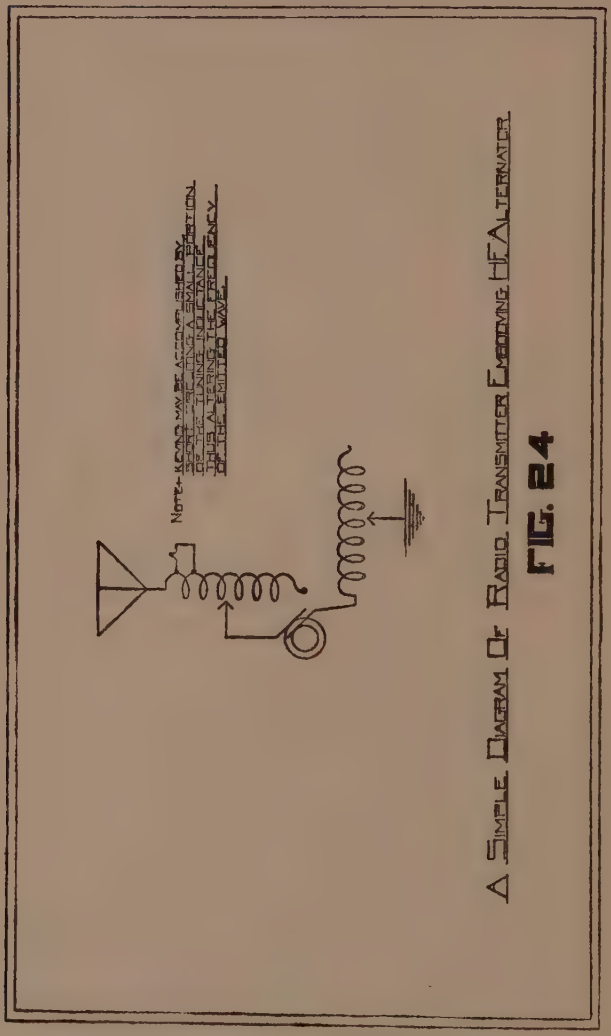
"A"—THE HIGH FREQUENCY ALTERNATOR

In our homes we have electric wiring to supply us with current for lighting, heating, etc. Usually this current comes from an electric generator of alternating current at some central station. It probably changes polarity (alternates) at the rate of about sixty cycles each second. Obviously this alternating current cannot be directly used for radio communication as it is of too low frequency. But other machines have been designed for radio work that generate alternating current of a frequency of many thousand cycles per second. These, then, in conjunc-

tion with the necessary tuning and keying systems, can be connected directly to an antenna and ground and used for communication purposes. The main drawback to this fundamentally simple method is the high cost of manufacture and upkeep of the machines. They are, therefore, used only in transcontinental or transoceanic stations where a great deal of business is handled, offsetting their high cost. The fundamental diagram of an alternator transmitter is shown in Figure 24.

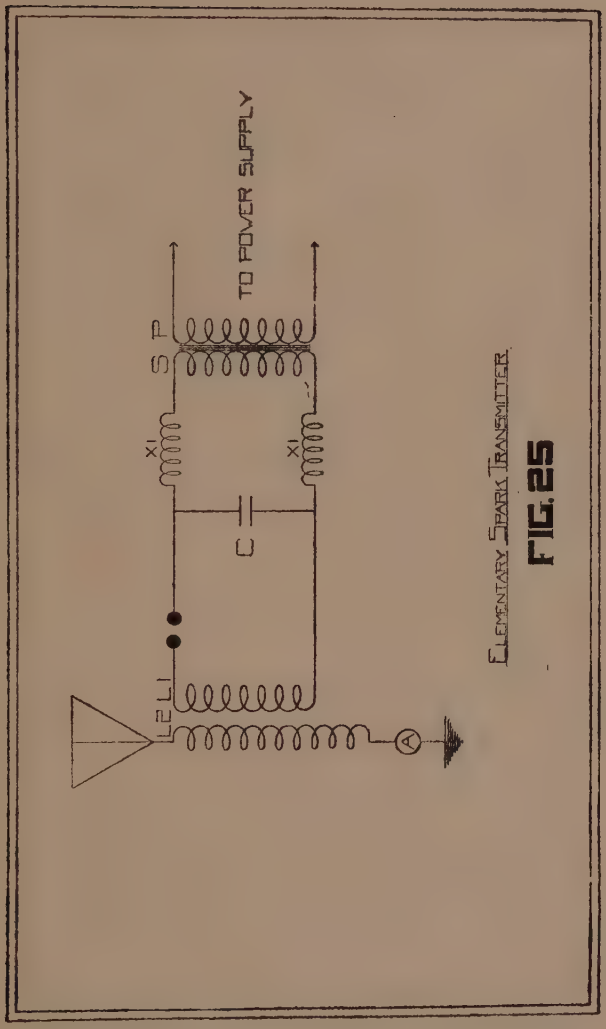
"B"—METHODS OF CHANGING LOW FREQUENCY ALTERNATING CURRENT TO RADIO FREQUENCY

The Spark Set.—Referring to Figure 25, the primary of the audio frequency transformer is fed by alternating current of low frequency. This is stepped up to a higher voltage in the secondary windings and is fed thru the radio frequency chokes "X1" & "X1" into a suitable condenser. For amateur work on 200 meters, the secondary voltage of the transformer may be from 8,000 to 25,000 volts, and the capacity of the closed circuit condenser should be about .007 Mf. The two terminals of the condenser are led to a series circuit comprising an inductance coil "L1" and a spark gap. This spark gap may be of the fixed, quenched, or rotary type. The condenser, gap, and inductance "L1" comprise the closed circuit of the transmitter, or the first radio frequency circuit. The purpose of the chokes "X1" & "X1" is to prevent any loss of radio frequency energy thru the windings of the audio frequency transformer. The closed circuit



A Simple Diagram Of Radio Transmitter Employing H.F. Alternator

FIG. 24

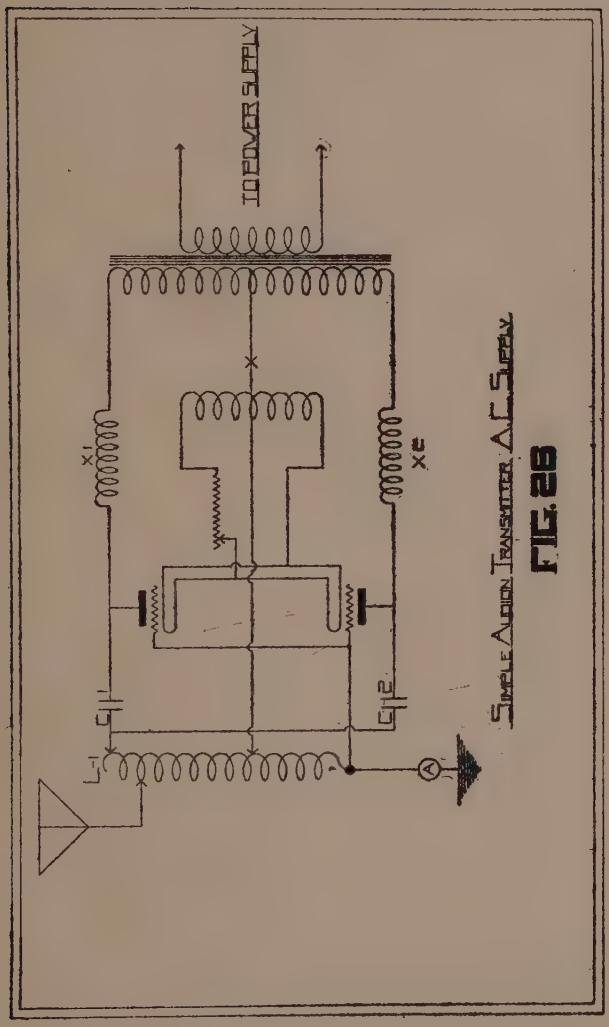


ELEMENTARY SPARK TRANSMITTER.

FIG. 25

is first tuned to the wave desired, and then coupled to the circuit containing inductance "L2". This circuit is called the "open" circuit, or "antenna" circuit. After the two circuits are adjusted to resonance, the transmitter is ready for operation. Care should be taken to see that all leads in the closed circuit are of heavy conductor and as short as possible. Due to the fact that radio frequency is generated only at each spark discharge across the gap, the output of the transmitter is necessarily in the form of *damped* waves. This may be obviated to some extent by the use of multiphase power supply, or by timed spark gaps. As most spark transmitters do not employ the latter systems, they therefore cannot be used for radio telephony. If a key is inserted in series with the power supply to the primary of the audio frequency transformer, telegraphy may be accomplished.

The Self-rectifying Audion Transmitter.—Referring to Figure 26, we have a power transformer with a primary winding suited to the voltage and frequency of the electric supply. The high voltage secondary delivers from 1,000 to 4,000 volts, depending upon the type of tube used. The voltage of the filament secondary likewise varies with the tube. Both secondaries have mid taps and are there connected together. A key may be inserted at the point marked "X" for telegraphic signaling. The radio frequency chokes "X1" & "X2" serve to prevent radio frequency leakage thru the transformer and may be made of 250 turns of No. 28 silk covered wire on an insulating cylinder 3" in diameter. *Do not use "Honeycomb" coils* for radio frequency chokes as their distributed capacity is relatively high, and there is danger of



SIMPLE ALDEN TRANSMITTER A.C. SUPPLY

FIG. 28

leakage. The ammeter may register the same apparent output for both types of windings but, in the case of the honeycomb coils, a portion of the current may be escaping to ground and thus serve no useful purpose. The condensers "C1" & "C2" may be between .001 and .005 Mf. capacity and serve to prevent short-circuiting the power supply. They should be rated at double the voltage of the power transformer. The auto transformer, or helix "L1" may be of 25 turns, of a type similar to the Radio Corporation of America "UL-1008". Note that a ground connection is shown. If a counterpoise is used, care must be taken to prevent leakage thru the filament transformer into the power lines and so into the ground. A grid leak and condenser in parallel or a "C" battery may be placed between the grids and the inductance if better operation is obtained thereby. If it is desired to use only one tube the circuit remains unchanged with the exception of the removal of one of the condensers and radio frequency chokes and half of the high voltage secondary winding of the power transformer. Only a radiation ammeter is indicated in the diagram, but if desired, a filament voltmeter and plate milli-ammeter may also be used and will be of great assistance. (This remark applies equally well to all transmitters using audions.) If the tubes will not, on any adjustment of the inductance, run with cold plates, the resistance of the antenna should be lowered, or the radio frequency leak found and stopped.

Inasmuch as the continuous wave emitted by this type of transmitter is already completely modulated, radio telephony is impractical and the output will resemble in tone that of a spark transmitter.

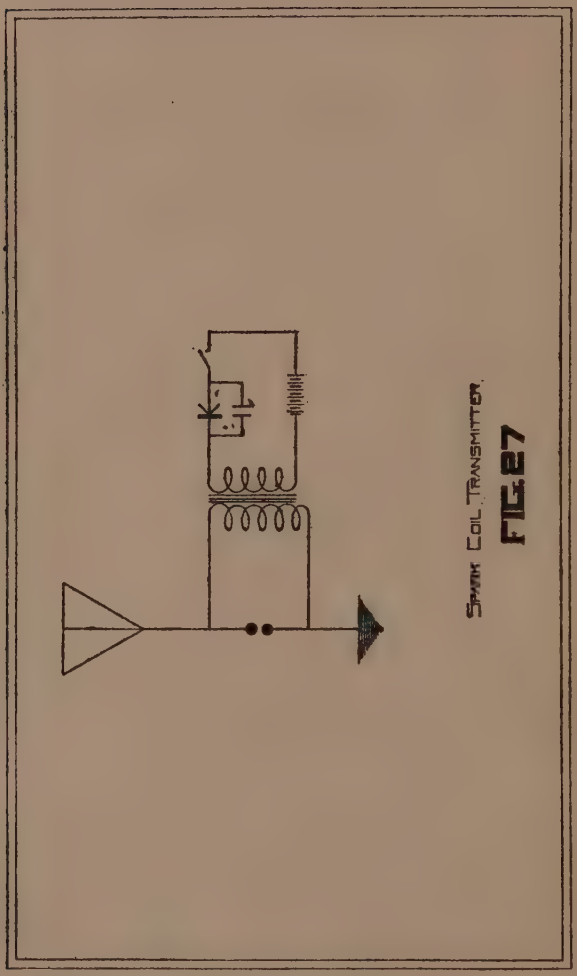
"C"—METHODS OF USING A DIRECT CURRENT SUPPLY TO OPERATE A RADIO FREQUENCY TRANSMITTER

The Spark Coil.—Figure 27 depicts the connections for a very simple spark coil circuit, comprising the direct current source of supply (shown in the figure as a battery of six cells), the coil itself: composed of interrupter, primary and secondary, and a spark gap. The antenna and ground being in parallel with the gap, and secondary of the spark coil.

This type of transmitter is used on many vessels as an emergency transmitter for the broadcasting of distress signals, for which it is peculiarly suited on account of its "broad" wave (high decrement.) This fact, coupled with its low range and strain on the antenna insulation, renders it unsuitable for general work. The reader is cautioned against employing one of these transmitters for his station, due to the difficulty in obtaining legal decrement of its radiated wave.

Other modifications of the same principle include power buzzers, and the use of the coupled circuit. The tone depends upon the adjustment of the interrupter. The set may also be operated on an A. C. supply.

The Arc.—Figure 28 depicts the connections for a fundamental arc transmission circuit. "G" is a direct current generator of about 500 volts. "R" is a variable resistor for power control. "X" is a radio frequency choke to prevent leakage into the generator windings. "L2" & "L3" are magnets to increase the size of the arc. "A" is a hollow copper electrode filled with water for cooling. "B" is a solid carbon electrode


SPARK COIL TRANSMITTER
FIG. 27

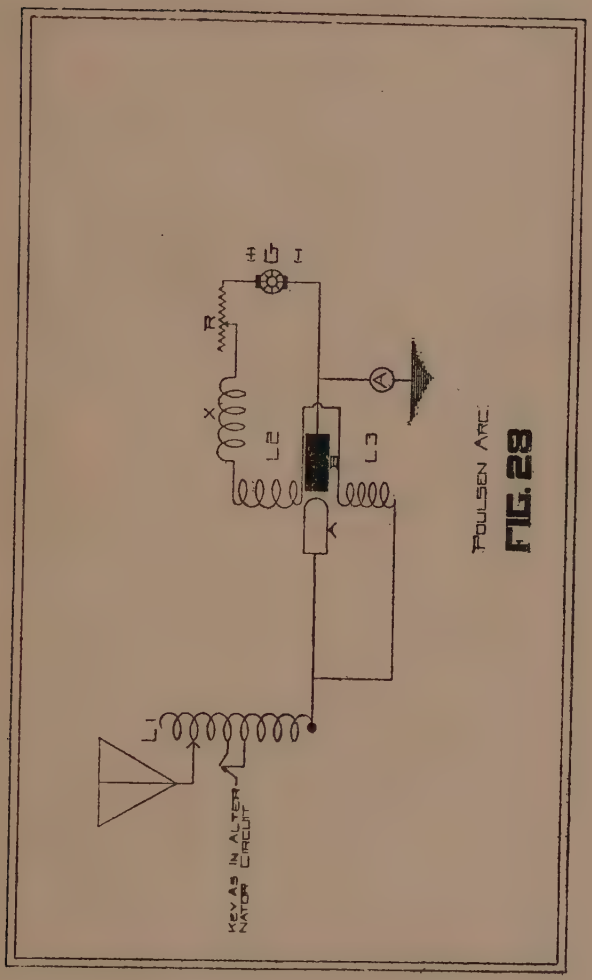


FIG. 28

(of similar construction to those used in motion picture projectors) and is usually rotated to obtain even deterioration. "L1" is a loading coil used to regulate the frequency of the oscillations. For best operation the antenna system should have a large capacity. Keying is accomplished by the compensation method, as in Circuit (Fig. 24.) The arc may be used for radio telephony, but since no efficient means has as yet been devised for modulation it will be found better suited for telegraphic signaling. The arc transmitter has found extensive application, of late, as a long range transmitter for ships. It may, however, be superseded by the audion transmitter as it seems possible to secure greater range with the latter type, the power input being equal.

To those inclined to examine the theory of operation, it will be seen that, in the circuit depicted, the condenser, that is, the antenna circuit, has the effect of throwing the voltage and current out of phase, and an alternating current is set up.*

The Audion Continuous Wave Transmitter.—Figure 29 depicts the connections for a simple audion transmitter for sustained (continuous) waves. The theory of operation of the oscillating audion generator of radio frequency currents whereby a direct current source is changed into radio frequency current will be taken up in the next chapter. This circuit is called the "Hartley" circuit, after its originator, Mr. R. V. L. Hartley of the Western Electric Co. It has found great favor among experimenters for many uses in receiving and transmitting sets, be-

* *For further details see "Principles of Radio Communication" by Prof. J. H. Morecroft.—"A simple explanation of the Operation of the Oscillating Arc", Page 583, et seq.)*

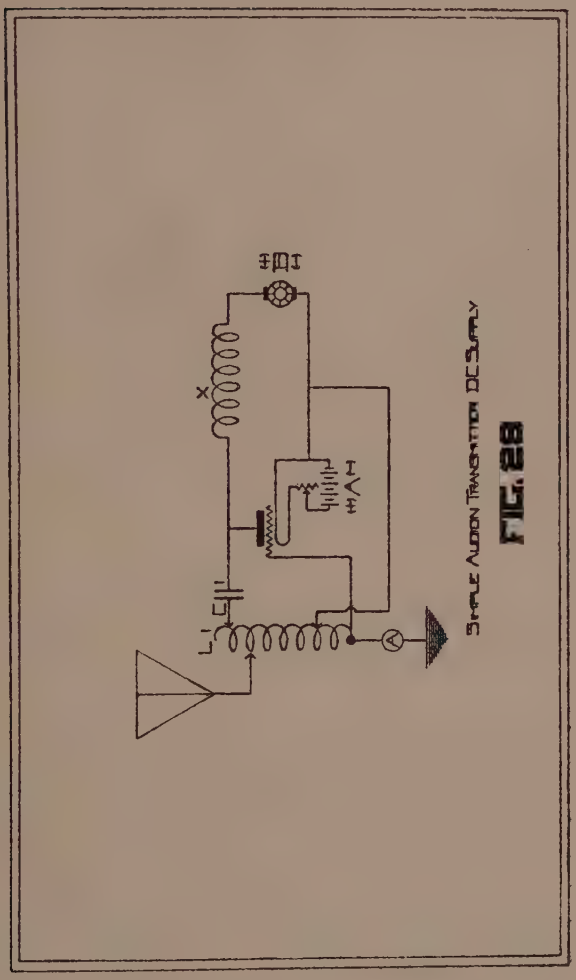


FIG. 28

cause it needs only a comparatively small amount of apparatus, and is a "sure-fire" oscillator.

Referring to Figure 29, "B" is a source of direct current, either a high voltage generator (depicted in the diagram) or a high voltage storage battery. The latter is more stable but requires a greater amount of attention, and, usually, a higher initial investment. The positive side of this source of high voltage direct current is fed to the plate of the audion thru the choke "X" which is placed there to prevent the radio frequency current generated by the audion from passing into the generator and so becoming lost. It may consist, for short wave work, of 250 turns of No. 28 silk covered wire wound in a *single-layer* on an insulating cylinder three inches in diameter. Honeycomb coils, due to their distributed capacity, are inefficient for this service. Radio frequency oscillations generated by the audion find a path thru the fixed "stopping" condenser "C1", which should be of the order of .002 Mf. and mica insulated. This condenser serves to prevent a short circuit of the high voltage direct current plate supply "B" thru the inductance "L1".

The filament may be heated by a storage battery or by a step down transformer. If the former is used, the negative plate supply should be connected to the negative side of the filament battery and the set may then be used with a counterpoise. A rheostat for adjustment of the filament may be placed in the positive lead. If a transformer is used, it must have a center tap. The negative plate supply is connected to this. Filament adjustment should be made from the primary of the transformer to avoid unbalancing the center tap. Due to the capacity of the secondary

of the transformer windings to ground, the set should now be grounded, as if a counterpoise be used, an appreciable amount of current, not necessarily showing up as a loss in the indicated antenna amperes, will escape to the ground.

The size of the inductance "L1" depends on the wavelength range to be covered by the set, and no especial dimensions need be given here. It should be of low resistance and good insulation in any case, and should not be placed near the choke coil "X".

In a low powered set, keying may be accomplished by breaking the plate supply or the antenna circuit, but in "high" power sets (20 watts and up) the key, shunted by a one microfarad condenser, should be placed in series with the grid. Also, in the higher powered sets, a grid condenser of about .002 Mf., shunted by a resistance of from 2,500 to 20,000 ohms may be placed to advantage, in series with the grid lead.

TYPES OF POWER SUPPLY FOR AUDION TRANSMITTERS

ALTERNATING CURRENT AT AUDIO FREQUENCIES

1. *Half wave self rectification.*

Figure 30 depicts the circuit connections for an A. C. plate supply. This is the simplest A. C. supply possible. The value of the transformer secondary depends upon the type of tube used, thus: 350 volts for a "5" watt tube, 1,000 volts for a "50" watt tube, and 2,000 volts for a "250" watt tube will be right.

An interesting variation of the above method, and one especially applicable to short distance work, is to use the house lighting current directly. For instance, in Manila, houses are supplied with 220 volt, 60 cycle

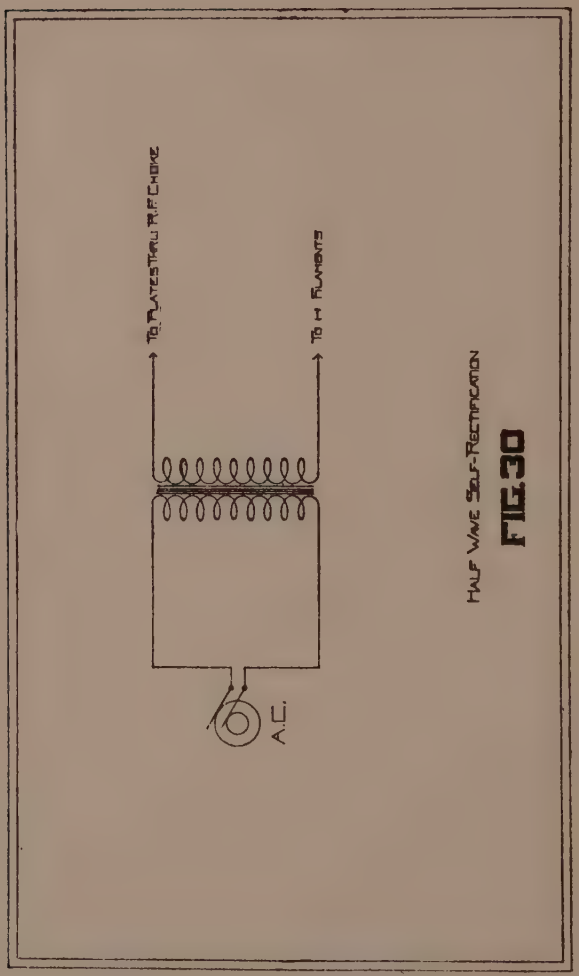
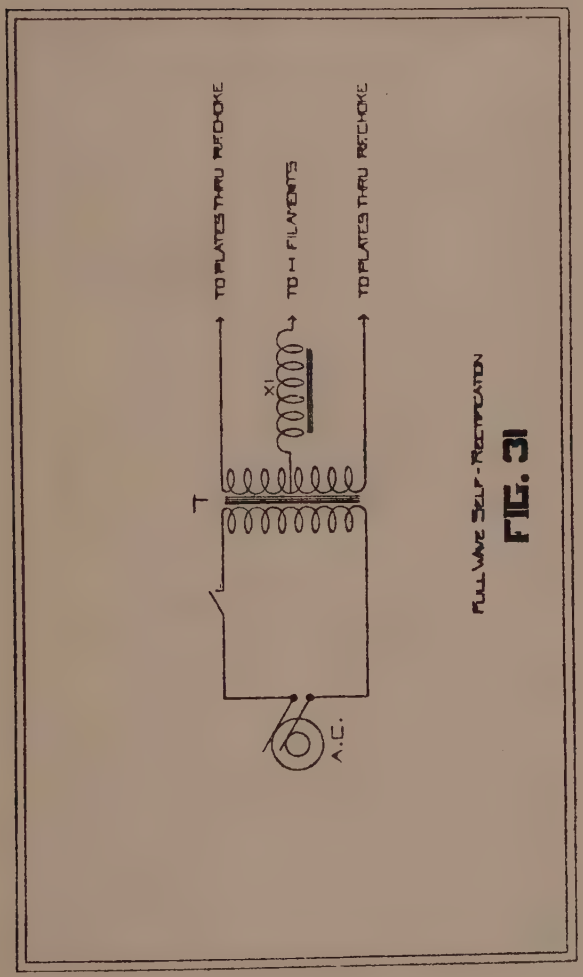

TO PLATES THRU R.F. CHOKE
TO H FILAMENTS
A.C.
HALF WAVE SELF-RECTIFICATION

FIG. 30



FULL WAVE SELF-RECTIFICATION

FIG. 31

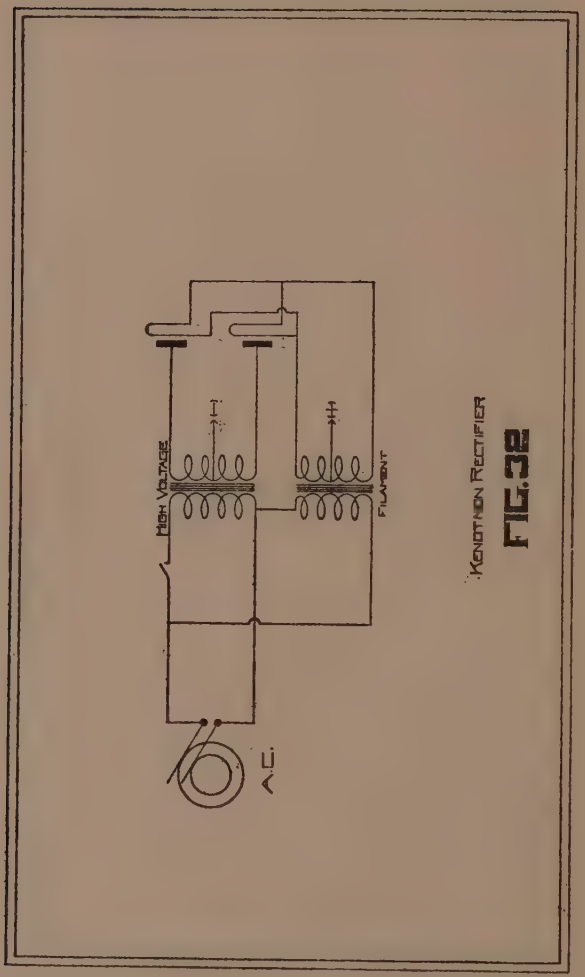


FIG. 32

current. First, determine which side of the house supply is grounded, then use that side to connect with the negative filament supply to the tube. The other side of the house current may be connected, thru a radio frequency choke, to the plate of a "5" watt tube. An insulated storage battery had better be used for filament excitation.

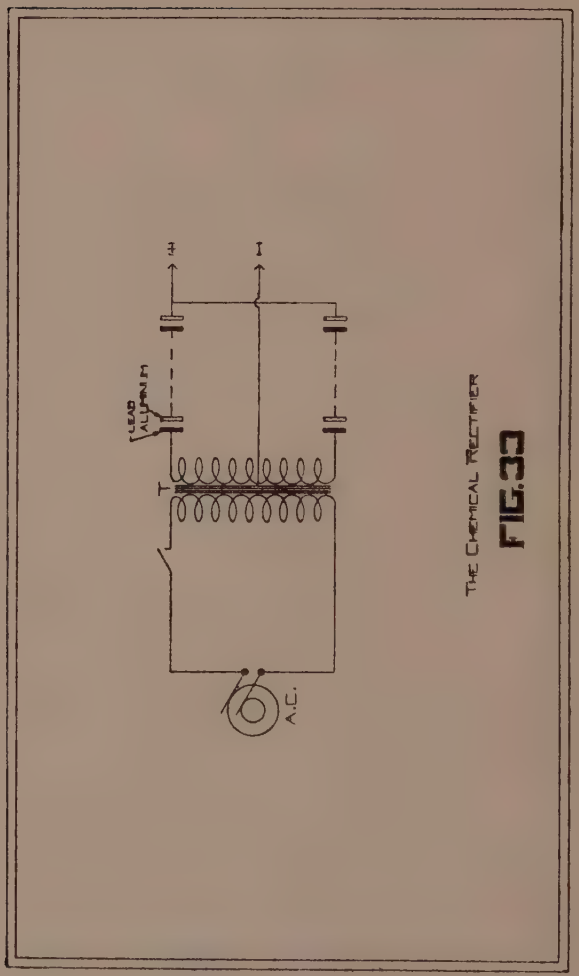
2. *Full Wave Self Rectification.*—Figure 31 depicts the connections for another Alternating current circuit. In this case, at least two identical tubes are needed. The emitted wave is modulated at twice the frequency as when using the circuit of Figure 30. This circuit may also be called a "completely modulated" C. W. (Continuous Wave) circuit.

"X1" is a smoothing reactor and should be as large as possible. It may be dispensed with, however, without serious loss.

3. *External Rectifiers*: (a)—*Kenotron.* In Figure 32 are shown the connections for the use of a Kenotron or Tungar rectifier. A separate transformer for excitation of the Kenotron filaments is necessary. The circuit is self explanatory.

(b)—*Chemical.* The Chemical or electrolytic rectifier is one extensively employed for amateur work. One jar (composed of a lead plate and an aluminum plate immersed in a glass cup full of borax solution) should be provided for every fifty volts. The cells must be given a charge to "form" the plates prior to their use. The power transformer used for regular transmission may be used for this work if care is taken to prevent overheating.

(c)—*The "S" Tube.* This rectifier is used much like a kenotron, but has the advantage that it has no filament to burn out, thus increasing its useful life.



THE CHEMICAL RECTIFIER

FIG. 33

The tube seems to be critical and should be used with a resistance, such as a 100 watt lamp, in series. Care should be taken to see that tubes with similar operating characteristics are obtained.

FILTERS

All the methods of power supply which we have discussed, with the exception of the storage battery, require a filter system. Even the motor generator does not supply straight direct current, on account of unevenness of commutation. The filter is employed to make the power supply as even and continuous as possible. One form of filter system is shown in Figure 34. This filter is equally applicable to rectified sixty cycle supplies or to a motor generator.

The iron core choke "L1" should have a rather high value—25 to 50 henries. In case such a value cannot be obtained, it would be well to increase the value of "C1" proportionally. About .5 Mf. is right for "C1" when "L1" is between 25 and 50 henries. After the transmitter is in operation, the values of "C1" and "L1" should be varied until best results are obtained.

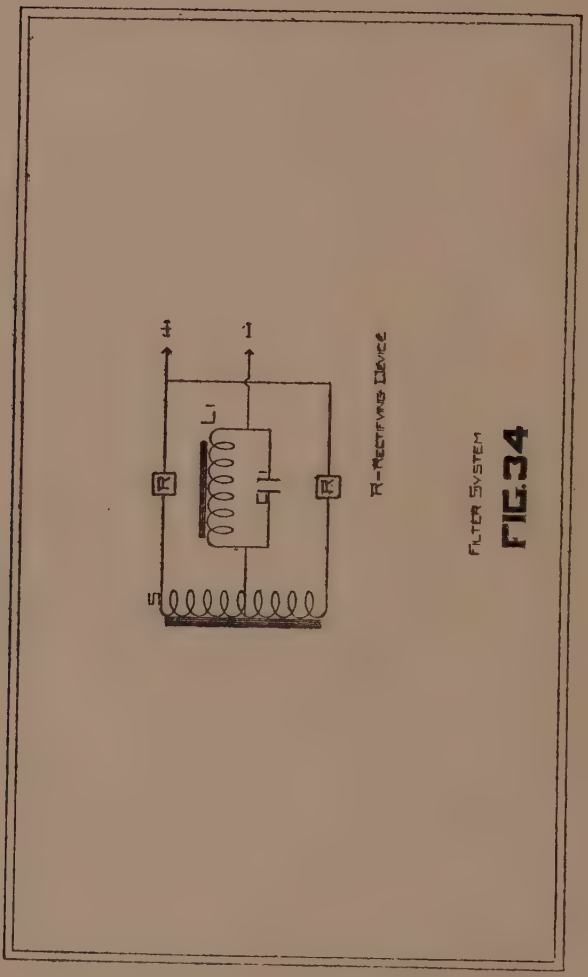


FIG. 34

A Filipino Amateur's Station

CHAPTER V

THE RADIO TELEPHONE

We learn in Chapter II that a continuous high frequency alternating current is necessary for radio telephony. It is easy to see why this is: In an ordinary spark, or damped wave transmitter the waves are constantly varying in amplitude (Height of wave) and there may even be short periods when no wave is going out at all. Obviously these waves cannot be modulated for the radiotelephone. Modulation means a variation in the average height of the radio frequency wave. The Damped waves are already "modulated" and, besides, they are not continuous.

What is needed, then, is a continuous alternating current wave of constant amplitude. Several transmitters produce this type of wave, but the one most easily modulated for radio telephone work is that using the oscillating audion. Before we go into the operation of the radio telephone let us see how the audion is made to generate alternating current.

Taking into consideration the circuit of Figure 35, let us assume that when the grid of the audion is positive with respect to the filament more current is allowed to flow from plate to filament from the battery "B". That is, the grid controls the number of electrons which carry this current. On the other hand, when the grid is negative with respect to the filament, current flow in the plate circuit is blocked.

Now presume the switch in the plate circuit to be closed. A current flow will be set up in the circuit containing the plate, the filament, the coil "L2", and

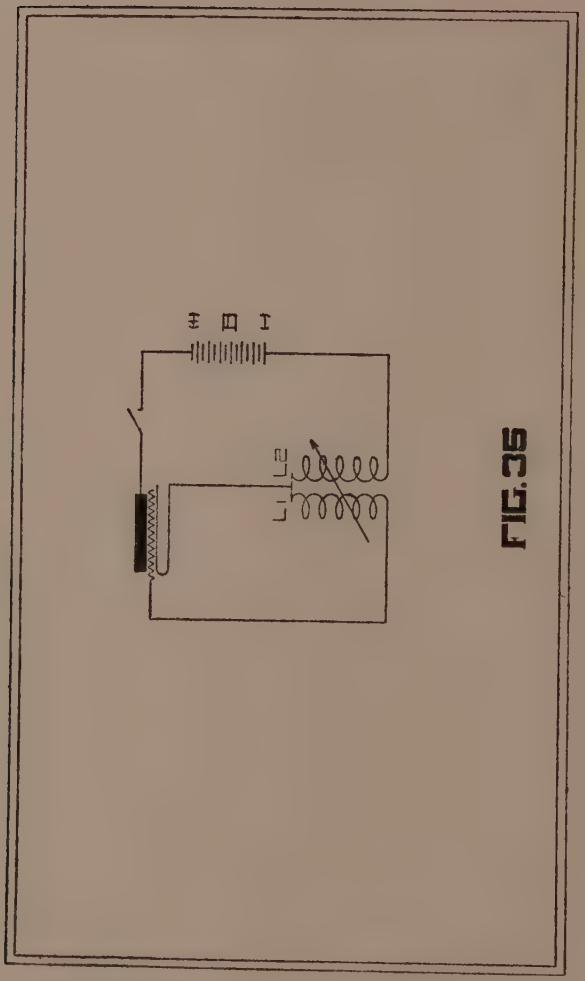


FIG. 35

OSCILLATING AUDION

the battery "B". An electronic flow from the filament allows passage to it of current from the plate of the tube. However, any current flow in the coil "L2" will set up a current flow in the circuit containing the coil "L1", as "L1" and "L2" are coupled together. If a positive charge is induced on the grid from "L2", then more current will flow in the plate circuit. Thus more current will be induced on the grid from the plate circuit and more and more current will flow until a point is reached when the tube will pass no more current. Then the charge on "L1" will collapse and the grid voltage will drop to zero. This will cause a decrease in the current flowing in the coil "L2" and thus place a negative charge on the grid. This negative charge will decrease the current flow in the plate circuit until same reaches a minimum, at which point the cycle will be reproduced.

By means of the foregoing method, oscillations may be produced by an audion at any radio frequency desired.

Since the waves generated by this type of transmitter are undamped [the process of generation being a continuous one, see Fig. 36(b), in contrast with the spark discharge and impact excitation of ordinary damped wave circuits, see Fig. 36(a)] any audio frequency changes made in its circuits will accurately mold the radio frequency component in corresponding fashion [See Fig. 36(c)]. In Figure 36 we have all the types of radio waves produced by transmitters in use today. In a spark set, as long as the key is held down, a series of wave trains similar to the one shown in Figure 36(a) will be produced. The waves of a continuous wave transmitter will resemble the curves of Figure 36(b). They have no decrement, because

(a)
DAMPED RADIO FREQUENCY OSCILLATION SUCH AS PRODUCED BY A SPARK TRANSMITTER
(b)
UNDAMPED RADIO FREQUENCY OSCILLATION SUCH AS PRODUCED BY AN AUDION TRANSMITTER
(c)
MODULATION ENVELOPE OF A CW RADIO FREQUENCY TRANSMITTER DISTORTED AT AUDIO FREQUENCY
FIG. 38

TYPES OF RADIO WAVES

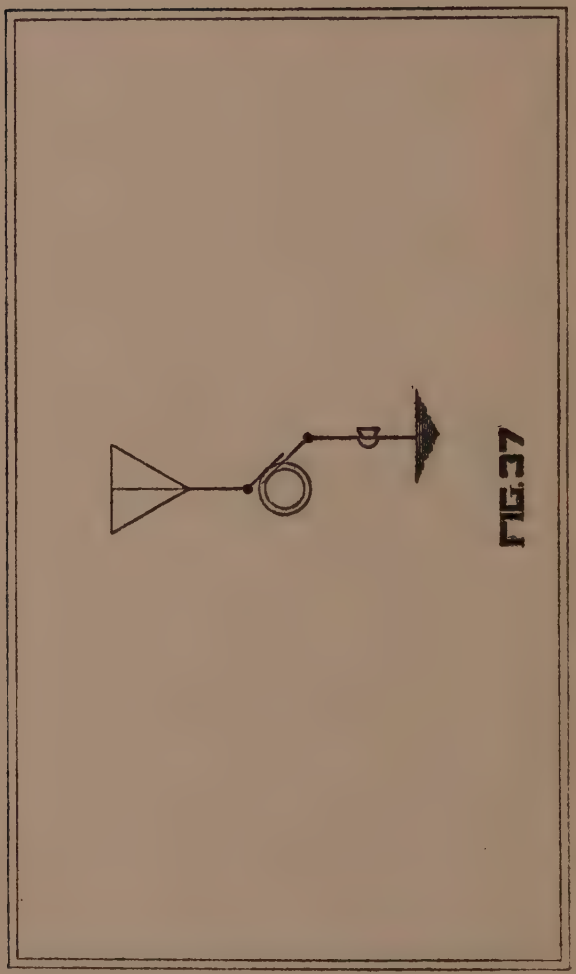
decrement is a measure of the difference in amplitude of succeeding crests of the same wave.

Now we have in Figure 36(c) the type of wave produced by a radio telephone transmitter. It will be seen that the waves are still of radio frequency, but their amplitude changes in direct proportion to the action of the microphone on the transmitter. It can also be seen that a radio telephone wave will have decrement and the decrement will depend upon the frequency of the modulation. In other words, the envelope of the output will resemble that of a damped wave, but the radio frequency component will still be continuous.

We have seen circuits that show how to generate a continuous wave by means of audions; now let us see how these waves are modulated or controlled by a microphone transmitter for speech.

Fundamentally, all radio telephone transmitters must contain two main parts, i. e., the generator of continuous waves and the device for modulating same at audio frequency. Of course, there is also the antenna, or radiating system, and the power supply, but these do not have to be considered just now, having been discussed previously. We have also seen how an audion generates high frequency continuous waves and so this part of the set presents no new feature.

Now then, all modulation systems in use at the present time depend upon either a resistance or a reactance placed in the power supply or in the radiation circuit of the generator (the H. F. generator) and controlled by a microphone. A "microphone" may be defined as a device for reproducing sound waves in the form of variation of an electric current flow. Thus, in a microphone circuit, the current flow



SIMPLEST RADIO TELEPHONE

is directly proportional to the intensity of the sound waves (in an ideal microphone).

Now let us see some radio telephone circuits that are modulated in the radiation circuit. This was the old form of modulation, because, before the advent of vacuum tubes, modulation of the power supply was practically impossible. One of the simplest circuits used in radio telephony is here shown, in Figure 37. This circuit was known and used as far back as 1905 and attempts have been made to use it since then up to the time audions came into use. Thus it can be seen that radio telephony is by no means as new as some people would have us believe. The circuit has the outstanding defect common to all modulation systems of this type, that is, it can only handle a limited amount of power. A method of increasing the amount of power handled by the microphone is shown in the circuit diagrams, Figure 38, (a) & (b). In Figure 38(a) the variation of the current flow through the microphone causes the permeability of the iron to change, and this changes the current in the heavy secondary coil, which is a part of the radiating circuit.

Figure 38(b) employs practically the same system, with the exception that there is no iron present to distort the modulation. The first circuit will probably, however, give a higher percentage of modulation.

Of the foregoing three methods of modulating the radiation, the one in Figure 38(b) is most commonly used, because of its simplicity and absence of distortion. A buzzer and key may be substituted for the microphone for local signalling.

When a microphone is used in series with any radiation circuit, it should be of low resistance.

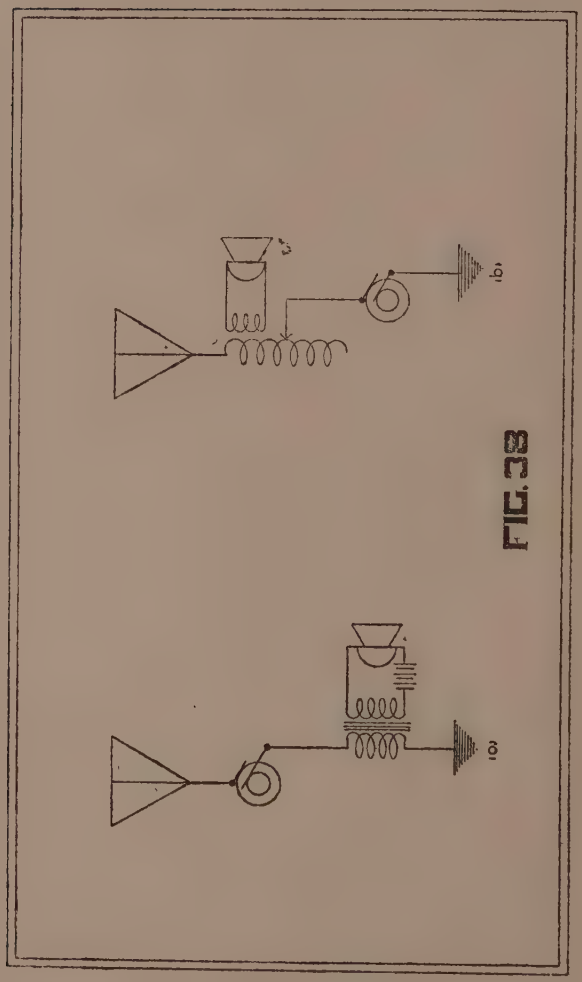


FIG. 38

ABSORPTION MODULATION

MODULATION OF POWER SUPPLY

There are two methods of modulating the power supply. The first entails modulating in the grid circuit and requires no extra audions. The second requires extra audions, of a number equal to those used for generating power. (Thus: If three audions are connected in parallel for generating power, then three more identical audions must be connected in parallel for modulating the first three audions.) These audions used for modulation do not make the transmitter any stronger as they do not generate any power.

I. *Grid Modulation.*—Figure 39 shows the standard Hartley circuit connected for use as a radio telephone employing grid modulation. The transformer "T" is an ordinary microphone or modulation transformer of low turns ratio, with a resistance of one or two megohms connected across its secondary to lessen distortion. To eliminate distortion reverse the polarities of the microphone battery or the transformer secondary. Changing microphones and the resistance across the secondary of the transformer will often help.

II. *Plate Modulation.*—This excellent form of modulation is practicable only when an extra set of modulating tubes (called the "modulator") and equal in power rating and number to the generating tubes (called the "oscillators") are employed. The circuit for connection of these extra tubes is shown in Figure 40. It was originated by Mr. R. A. Heising of the Western Electric Co., and is named after him.

This circuit is an elementary one, consisting of the Hartley oscillator circuit with Heising modulation. The tubes shown may be only two or they may be many: the only rule to remember being that for every

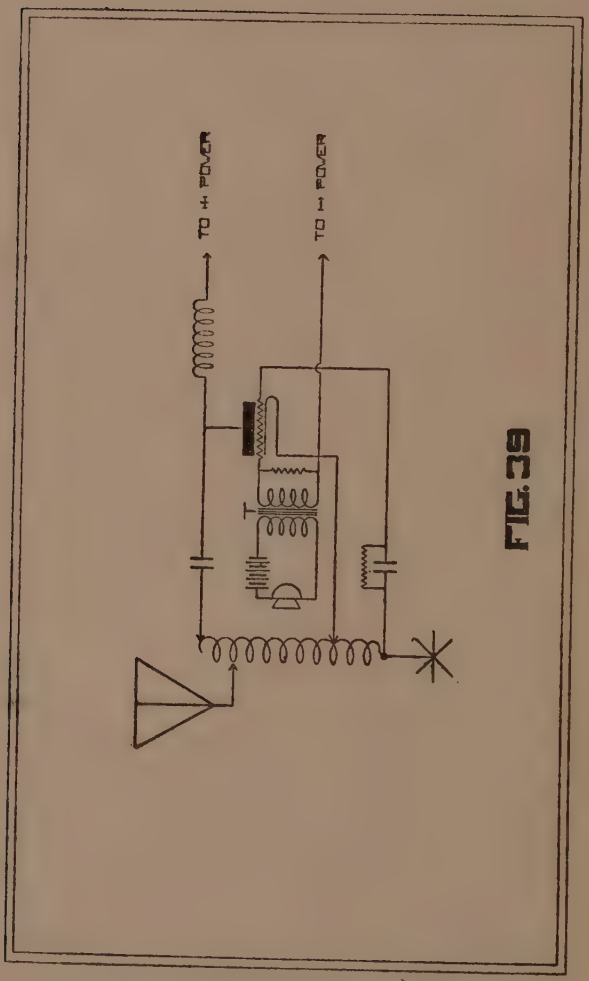


FIG. 39

GRID MODULATION

tube in the oscillator there must be another identical tube in the modulator. The oscillator connections and constants are all the same as in a telegraph set. The choke "X1" is the usual one wound on an air core to prevent loss of radio frequency current. The choke "X" is the most important part of the circuit. It is an iron core audio frequency coil and may be of about six henries inductance. Its purpose is to prevent changes in the amount of current fed the plates of the tubes; for this reason it is known as a "constant current" choke. Any change in the amount of current drawn by the modulator tube, (or tubes) will change the amount of power fed the oscillator tubes. It is easy to see, then, that these changes in the plate current of the oscillator tube (or tubes) will show up in the ether in the form of changes in the amplitude of the emitted waves.

For example: Let the total amount of current fed both tubes be represented by the letter "A". This amount of current is held constant by the choke "X". Now let the average amount of varying current drawn by the modulators be represented by the unknown quantity "X". The oscillator current will then be (when current is being drawn by the modulators) "A-X". When no current is being drawn by the modulators it will, of course, be "A". The oscillator plate current, swinging between the two extremes "A-X" and "A" will cause corresponding variations in the amplitude of the radio frequency component, which is the result desired.

The fidelity of similitude between the original sound waves impinging upon the microphone, and the corresponding variation in amplitude of the radio frequency component will depend, to a major degree,

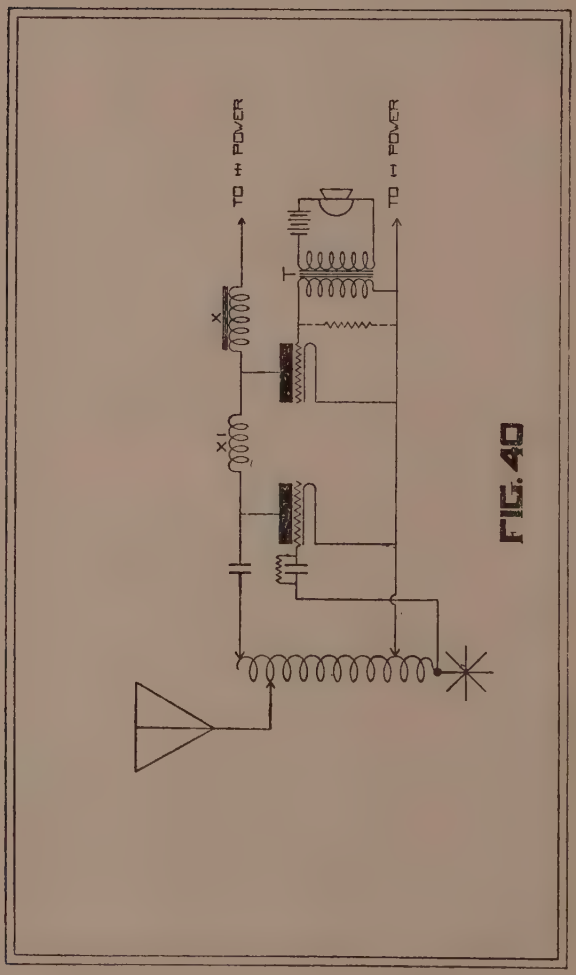


FIG. 40

PLATE MODULATION

upon the construction of the microphone, the microphone transformer, and the constant current choke in the common plate lead. All these factors enter into the distortion of the original sound wave. If it is the microphone that causes the distortion, try several different ones, or, if only one is available, try changing the strength and reversing the polarity of its battery. Similarly, if another transformer is not available, try reversing its primary and secondary terminals, and putting different values of resistance across its secondary. Two megohms is about right to start with. As for the choke, others will have to be substituted until optimum results are obtained.

An elaboration of Figure 40 is given in Figure 41. Further circuits are unnecessary, for, if the constructor already has the foregoing fundamental facts quite assimilated, he will be competent to plan his own "hookups".

In Figure 41 is depicted the circuit diagram for an elaborate radio telephone transmitter, consisting of a Hartley type oscillator, controlled by a Heising type modulator. There is also a one stage microphone amplifier. Various meters are also shown. The reader has already met the various parts of this circuit, but a detailed description is here given:

Antenna Ammeter.—Should have a 50% higher reading than the expected "radiation". Thus if one ampere is expected, get a *Radio Frequency* ammeter reading up to one and one-half amperes.

Antenna Series Condenser.—Denoted in Figure 41 by the symbol "C4". Is extremely valuable in making slight changes in the wavelength. A value of about .0005 Mf. (Maximum) will be found useful.

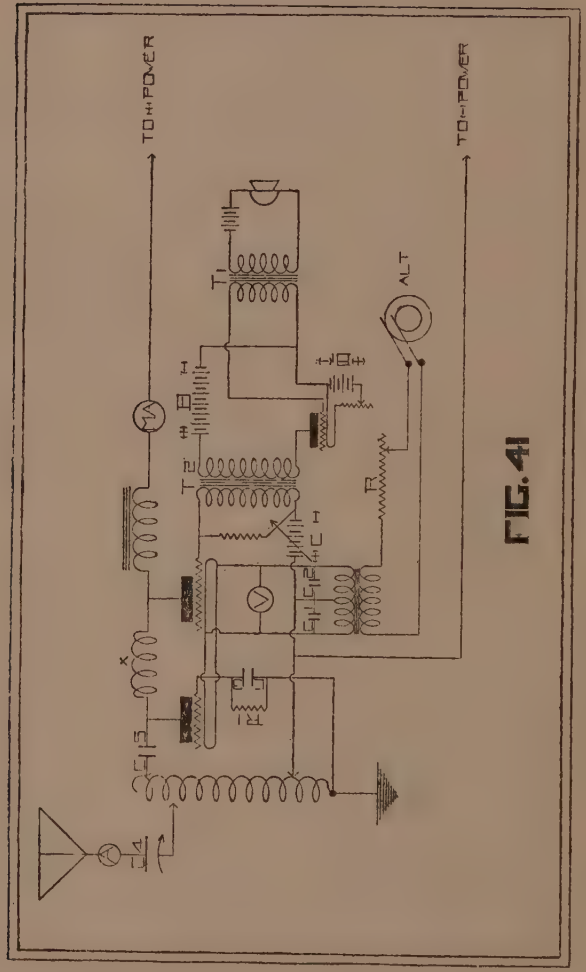


FIG. 41

ELABORATE TELEPHONE TRANSMITTER

Grid Condenser and Resistance.—"C3" and "R1". The former should be a mica insulated condenser of .002 Mf. capacity. The resistance should be variable from 2,500 to 10,000 ohms. It should be mounted in such a way as to afford maximum cooling. NOTE: The lead from the grids of the oscillator tubes to the inductance should be as short and direct as possible. This is extremely important.

Radio Frequency Choke.—Denoted by the symbol "X". Only one is necessary. *Do not Use Honeycomb or Multilayer Coils.* A single layer choke is the thing to use. Directions for its manufacture were given in Chapter Four. Do not place this choke near the antenna inductance.

Constant Current Choke.—The type of choke to use here has already been described. Try several until you get the one that works the best. On low powered sets, any iron core inductance may be used. Try secondaries of amplifying transformers, primaries of bellringing transformers, etc. Remember that upon this choke depends the successful modulation of your set. Sometimes the iron core chokes in the filter system will take the place of this choke.

The Milliammeter.—"MA". This should be a Direct Current instrument and have a 50% overload factor. Compute the amount of milliamperes drawn by both sets of tubes, then get an ammeter that reads 50% over this amount. An instrument that is quick to respond to slight changes of current, such as the "thermo couple" type, will prove valuable, as this meter will show (approximately) the percentage of modulation, and prove a valuable check on it.

The Filament Supply.—In case of an alternating current supply to the operating room, the alternator

"ALT" may be dispensed with. The rheostat "R" is in the primary of the filament transformer. Do not put this rheostat in the secondary. The transformer itself should be well insulated and have ample capacity for all tubes. The secondary must have a center tap. The condensers "C1" and "C2" may be of any available size from .001 to 1.0 Mf. that will stand the voltage. The larger capacities are usually the better. *The A. C. filament voltmeter* should also have a 50% overload factor and is rather an important instrument, as the manufacturers claim that a small increase in the filament voltage will greatly reduce the life of the tube, whereas a small decrease of the voltage will double its life. Due to the present rather high price of transmitting tubes, this meter, especially when used with the larger sizes, will often pay for itself many times. It should be the first meter the prospective builder purchases!

Bypass Condenser.—"C5". Mica insulated. .002 to .005 Mf. Capacity. To stand double the maximum plate voltage.

The Amplifying Apparatus is quite important, as it may introduce considerable distortion. "T2" should have a flat amplification curve (i. e., amplify equally well at all normal audio frequencies). Do not use excessive voltage on the plate of the amplifying tube.

If it is desired to use the set with a counterpoise radio frequency chokes must be placed in the leads to the A. C. supply for the filament transformer, or a well insulated storage battery used. This is a place where radio frequency leakage often occurs.

If distortion is experienced with the amplifying circuit of Figure 41, substitution of the choke coil amplifier of Figure 42 will usually eliminate same.

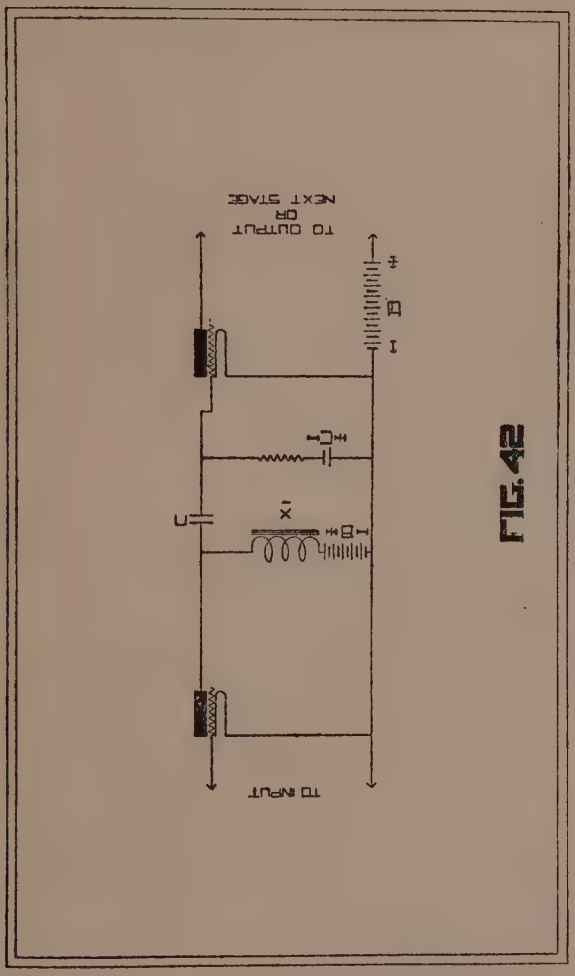


FIG. 42

REACTANCE COUPLED AMPLIFIER

Take note that the voltage impressed on the grid of the second tube depends upon the reactance of "X1". Try various forms of iron chokes in the circuit until the suitable type is found. "C" is an ordinary grid or bypass condenser. The grid resistance may be of about two megohms.

HOW TO SET THE STATION IN OPERATION AND VARIOUS FAULTS THAT MAY BE FOUND

Before the actual construction of the instruments is begun a few warnings will be apropos. The following suggestions may also apply to receiving sets:

1. Use only a single layer coil for the radio frequency choke.
2. Keep the radio frequency choke and the main inductance well separated.
3. Make all grid leads short.
4. If several tubes are being operated in parallel, see that all the leads to grids and plates are of the same length. NOTE: A radio frequency choke made by winding about 30 turns of No. 28 S. S. C. wire on a one inch form, placed in each grid lead will be of assistance in preventing parasitic oscillations.
5. If the set does not oscillate, try reversing the grid coil so as to obtain proper feedback.
6. Be sure the grid leak is not burned out.
7. In receiving sets, reversing tickler connections will often give better operation.
8. See that the center tap on the filament transformer is not unbalanced.
9. See that plate supply is of right polarity and sufficient voltage.
10. If set oscillates, but plates of tubes are red, reduce resistance of radiation system.

11. If set draws power, but does not "put out" well—find the radio frequency leaks.

12. *Do not try to adjust the set with the power on.*

13. While making preliminary adjustments always reduce power at least 50%.

14. A handy test for determining the polarity of any D. C. current supply is to fill a glass or crockery bowl with water to which a pinch of salt has been added. Immerse the wires in the water, separating them about a foot. Bring them together slowly and observe from which wire the most bubbles arise. This is the negative lead.

15. If it is desired to determine whether a certain current supply is delivering the proper voltage and no voltmeter is at hand, place enough low wattage lamps in series to equal the normal voltage (i. e., if the normal voltage is 1,000, place four or five 220 volt lamps in series). Close the circuit with a fuse and observe whether or not the lamps light up to full brilliancy. If they do not, the supply is not delivering normal voltage.

Since radio apparatus is, at present, somewhat difficult to obtain in the Philippines, the following suggestions will be welcomed by the experimenter:

The ordinary Ford coil, used for ignition purposes, has a multiplicity of radio uses. Besides making a complete "plain aerial" spark transmitter, it can be used as a microphone transformer for radio telephone work, or as a source of plate supply for Interrupted C. W. transmitters. For receiving it may be used for amplification in the form of a transformer, or as a reactance. It may also be used to replace the burned out coil on a Magnavox loud-speaker, etc. A great many similar uses will doubtless occur to the reader.

A 40-watt lamp, placed in series with the "B" battery will prevent burning out the filaments of audions from accidental short circuit.

Glass plate condensers are easily made. Some tinfoil or sheet copper, and clean photo plates are the nuclei.

A very good antenna insulator for amateur work may be made from a pickle or olive bottle. Glass towel bars are also good.

If the amateur has no soldering iron, he may use his storage battery and a piece of carbon to generate an arc that will melt solder. A lead pencil may be used, in some cases.

Inexpensive filament voltmeters and plate milliammeters may be made from the small pocket "dry cell testers" sold by most garages. They may be recalibrated by comparisons with more costly instruments.

Bulkhead or lead-in insulators may be made from a sheet of plate or windowglass. Pass a threaded bolt thru a hole in the center of the sheet and provide same with nuts and lead washers.

A quick method of determining burnt out windings in amplifying transformers, etc., is to place one dry cell in series with a pair of high resistance telephone receivers and touch the two terminals thus formed to the terminals of the coil under test. A loud click will be heard if the winding is in good condition. Practice will render one apt in telling whether the coil is open, in good condition, or short circuited. This method may also be used to determine short circuits in condensers.

Fuses for high voltage plate supplies may be made of narrow pieces of thin tinfoil. This may be cut

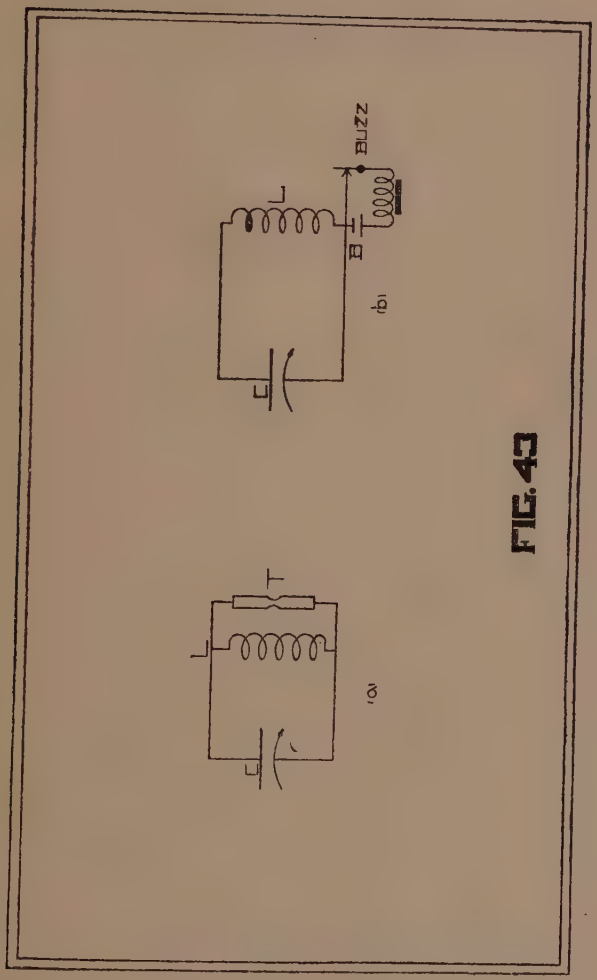


FIG. 43

WAVEMETER CIRCUITS

with scissors between pieces of paper. Allow about two inches for every thousand volts.

A wavemeter is an instrument that every receiver owner or transmitter operator should possess. A very accurate standard instrument can be purchased for about the same price as a receiving set. Figure 43 (a) and (b) show constructional circuit diagrams for wavemeters:

In Figure 43(a), we see the connections for a wavemeter suitable for use in the adjustment of transmitters. The Condenser "c" (for ordinary amateur and broadcast use) had better have a maximum capacity of .0005 Mf. and be of "low loss" construction. The size of coil "L" varies according to the wavelength band it is desired to cover. "T" is a neon tube such as is sold in the "Spark-C" and "Airco" ignition testing devices for automobiles.

In Figure 43 (b) we have the circuit diagram for a wavemeter to calibrate receiving sets. The condenser "C" and inductance "L" may be the same as used in circuit [Fig. 43(a)] but will have to be recalibrated for this work. To operate, the inductance coil is placed near the receiver and the capacity of the wavemeter condenser varied until the loudest response from the wavemeter buzzer is obtained in the telephone receivers connected to the receiving set. Consultation of the wavemeter calibration curve will then establish the wavelength of the receiver.

It is needless to add, that in both the coil and condenser, the construction should be of the best obtainable. The dial on the condenser must be firmly attached to the shaft thereof to prevent changes after the setup has been calibrated.

When the wavemeter has been made it may be calibrated by comparison with a standard in the presence of a radio frequency "driver".

Reliable wavemeters, suitable for calibration purposes, are in the hands of the Bureau of Posts, in Manila.

CHAPTER VI

FORMULAS FOR VARIOUS COMPUTATIONS AND THE UNDERWRITER'S REGULATIONS REGARDING THE INSTALLATION OF RADIO APPARATUS

The Use of Ohm's Law.—Three factors are of major worth in computing electrical values, namely: *Voltage, Current* and *Resistance.*

Ohm's Law is usually expressed in the form of an equation whereby the third factor can be easily found when two are known. Briefly, if

C = Current.
V = Voltage.
and R = Resistance,

Then $C = \frac{V}{R}$ (1), that is, the current in any circuit always equals the quotient obtained by dividing the voltage in the same circuit by its resistance.

Similarly $R = \frac{V}{C}$ (2) and $V = C \times R$ (3).

These equations find application in solving various electrical problems.

Example: If I have a dry cell with a difference in potential (voltage) of 1.6, and, upon connecting an ammeter across the terminals read an amperage of 28, what is the total resistance in the circuit, including that of the meter and dry cell?

Ans.—From (1) $28 = \frac{1.6}{R}$, $280R = 16$.

Then R = .057 ohms (to three places).

Other uses of these equations will doubtless suggest themselves to the reader.

Series Connections for Resistances.—If a number of resistances "r1", "r2", "r3", and "r4", etc., are connected in series, the resulting equivalent resistance is expressed by the following equation:

$$R = \text{"r1"} + \text{"r2"} + \text{"r3"} + \text{"r4"}, \text{ etc.}$$

Parallel Connections for Resistances.—If a number of resistances "r1", "r2", "r3", "r4" are connected in parallel, the resulting equivalent resistance is expressed by the following equation:

$$\frac{1}{R} = \frac{1}{\text{"r1"}} + \frac{1}{\text{"r2"}} + \frac{1}{\text{"r3"}} + \frac{1}{\text{"r4"}}$$

Series Connection for Condensers.—If a number of condensers "c1", "c2", "c3", "c4", etc., are connected in series, the resulting capacity will be equivalent to the value obtained from the following equation:

$$\frac{1}{C} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} + \frac{1}{C4}$$

Parallel Connection for Condensers.—If a number of condensers, "c1", "c2", "c3", "c4", etc., are connected in parallel, the resulting capacity will be equivalent to the result obtained from the following equation:

$$C = \text{"c1"} + \text{"c2"} + \text{"c3"} + \text{"c4"}, \text{ etc.}$$

Effective Capacity of an Antenna System.—Find the wavelength of the antenna system with a standard wavemeter. Next disconnect the antenna and ground leads and connect into the circuit a calibrated variable condenser and tune the circuit to the same wavelength. Read the capacity of the condenser: this is the capacity of the antenna for that particular wavelength. Repeat for a multiplicity of wavelengths.

Fundamental Wavelength of an Antenna.—Connect into the antenna circuit a small amount of variable inductance. Plot a curve, using amount of inductance as abscissae and the wavelengths as ordi-

nates. At a point on the curve corresponding to zero inductance will be found the fundamental wavelength.

To Measure the Antenna Resistance.—Connect the antenna system to a transmitter, including in the circuit an antenna ammeter. Read the current "I" when the antenna is normal. Now insert a known resistance "R" of a few ohms in series with the ground lead and read the current "I1". Then the antenna resistance is given by the equation:

$$\text{"Ra"} = \frac{R}{\frac{I}{I1} - 1}$$

This experiment should be repeated at many wavelengths and with various values of "R".

FIGURE 44

Prefix	Abbreviation	Meaning
micro	u	One millionth
milli	m	One thousandth
centi	c	One hundredth
deci	d	One tenth
deka	dk	Ten
hekto	h	One hundred
kilo	k	One thousand
mega	M	One million

DEFINITIONS: *Ohm.*—Resistance of a quantity of mercury at the temperature of melting ice, 14.4521 grams in mass, of uniform cross section and a length of 106.30 centimeters.

Ampere.—The current which when passed thru a solution of silver nitrate in water in accordance with certain specifications deposits pure silver at the rate of 0.0011180 of a gram each second.

Volt.—The electromotive force (E. M. F.) which produces a current of one ampere when steadily applied to a conductor the resistance of which is one ohm.

Watt.—The power expended by a current of one ampere in a resistance of one ohm.

Henry.—The inductance in a circuit in which the electromotive force induced is one volt when the inducing current varies at the rate of one ampere per second.

Farad.—Capacity of a condenser in which a potential difference of one volt induces a charge of one coulomb.

Coulomb.—Quantity of electricity transferred by a current of one ampere in one second.

Horsepower.—746 watts.

Ratio π (pronounced "pi") of circumference to diameter in any circle—3.14159265 (to 8 decimal places).

FIGURE 45

RESISTANCE OF COPPER WIRE

Standard annealed copper, solid conductor, at 68° Fahrenheit. For direct current and for alternating current of frequency of 1,500,000 cycles per second (wave length = 200 meters). The sizes shown are American wire gauge (Brown & Sharpe).

Size.	Ohms per 1,000 feet		Size.	Ohms per 1,000 feet	
	D. C.	At 200 m.		D. C.	At 200 m.
00.....	0.07793	3.369	20.....	10.15	40.88
0.....	.09827	3.784	21.....	12.80	46.30
1.....	.1239	4.254	22.....	16.14	52.50
2.....	.1563	4.784	23.....	20.36	59.55
3.....	.1970	5.374	24.....	25.67	67.72
4.....	.2485	6.045			
			25.....	32.37	77.0
5.....	.3133	6.798	26.....	40.81	87.8
6.....	.3951	7.64	27.....	51.47	100.2
7.....	.4982	8.60	28.....	64.90	114.1
8.....	.6282	9.67	29.....	81.83	129.7
9.....	.7921	10.88			
			30.....	103.2	148.0
10.....	.9989	12.24	31.....	130.1	170.3
11.....	1.260	13.79	32.....	164.1	199.2
12.....	1.588	15.54	33.....	206.9	236.5
13.....	2.003	17.49	34.....	260.9	285.2
14.....	2.525	19.72			
			35.....	329.0	348.7
15.....	3.184	22.22	36.....	414.8	431.4
16.....	4.016	25.10	37.....	523.1	536.2
17.....	5.064	28.32	38.....	659.6	670.0
18.....	6.385	32.00	39.....	831.8	840.1
19.....	8.051	36.10	40.....	1049.	1055.7

THE INTERNATIONAL TELEGRAPH CODE

Attempts should not be made to master the code by visual practice. In radio, it is *sound* that must convey the message to the brain. In the following code: "did" or "dit" stands for a *dot* and "dah" for a *dash.* The best way to memorize the code is to say the different signs *out loud,* at the same time repeating the corresponding letters and numerals:

A—did dah
B—dah dit dit dit
C—dah did dah dit
D—dah dit dit
E—dit
F—did did dah dit
G—dah dah dit
H—dit dit dit dit
I—dit dit
J—did dah dah dah
K—dah did dah
L—did dah dit dit
M—dah dah
N—dah dit
O—dah dah dah
P—did dah dah dit
Q—dah dah did dah
R—did dah dit
S—dit dit dit
T—dah
U—did did dah
V—did did did dah
W—did dah dah
X—dah did did dah
Y—dah did dah dah
Z—dah dah dit dit
1—did dah dah dah dah
2—did did dah dah dah
3—did did did dah dah
4—did did did did dah
5—dit dit dit dit dit
6—dah dit dit dit dit
7—dah dah dit dit dit
8—dah dah dah dit dit
9—dah dah dah dah dit
0—dah dah dah dah dah

FIGURE 46

EQUIVALENT VALUES—KILOCYCLES TO METERS OR METERS TO KILOCYCLES

10	29980	400	749.6	790	379.5	1190	252.0	1590	188.6
20	14990	410	731.3	800	374.8	1200	249.9	1600	187.4
30	9994	420	713.9	810	370.2	1210	247.8	1610	186.2
40	7496	430	697.3	820	365.6	1220	245.8	1620	185.1
50	5996	440	681.4	830	361.2	1230	243.8	1630	183.9
60	4997	450	666.3	840	356.9	1240	241.8	1640	182.8
70	4283	460	651.8	850	352.7	1250	239.9	1650	181.7
80	3748	470	637.9	860	348.6	1260	238.0	1660	180.6
90	3331	480	624.6	870	344.6	1270	236.1	1670	179.5
100	2998	490	611.9	880	340.7	1280	234.2	1680	178.5
110	2726	500	599.6	890	336.9	1290	232.4	1690	177.4
120	2499	510	587.9	900	333.1	1300	230.6	1700	176.4
130	2306	520	576.6	910	329.5	1310	228.9	1710	175.3
140	2142	530	565.7	920	325.9	1320	227.1	1720	174.3
150	1999	540	555.2	930	322.4	1330	225.4	1730	173.3
160	1874	550	545.1	940	319.0	1340	223.7	1732	173.2
170	1764	547.6	547.6	950	315.6	1350	222.1	1740	172.3
173.2	1732	560	535.4	960	312.3	1360	220.4	1750	171.3
180	1666	570	526.0	970	309.1	1370	218.8	1760	170.4
190	1578	580	516.9	980	305.9	1380	217.3	1770	169.4
200	1499	590	508.2	990	302.8	1390	215.7	1780	168.4
210	1428	600	499.7	1000	299.8	1400	214.2	1790	167.5
220	1363	610	491.5	1010	296.9	1410	212.6	1800	166.6
230	1304	620	483.6	1020	293.9	1420	211.1	1810	165.6
240	1249	630	475.9	1030	291.1	1430	209.7	1820	164.7
250	1199	640	468.5	1040	288.3	1440	208.2	1830	163.8
260	1153	650	461.3	1050	285.5	1450	206.8	1840	162.9
270	1110	660	454.3	1060	282.8	1460	205.4	1850	162.1
280	1071	670	447.5	1070	280.2	1470	204.0	1860	161.2
290	1034	680	440.9	1080	277.6	1480	202.6	1870	160.3
300	999.4	690	434.5	1090	275.1	1490	201.2	1880	159.5
310	967.2	700	428.3	1100	272.6	1500	199.9	1890	158.6
320	936.9	710	422.3	1110	270.1	1510	198.6	1900	157.8
330	908.6	720	416.4	1120	267.7	1520	197.2	1910	157.0
340	881.8	730	410.7	1130	265.3	1530	196.0	1920	156.2
350	856.6	740	405.2	1140	263.0	1540	194.7	1930	155.3
360	832.8	750	399.8	1150	260.7	1550	193.4	1940	154.5
370	810.3	760	394.5	1160	258.5	1560	192.2	1950	153.8
380	789.0	770	389.4	1170	256.3	1570	191.0	1960	153.0
390	768.8	780	384.4	1180	254.1	1580	189.8	1970	152.2

EQUIVALENT VALUES—*Continued*

1980	151.4	2430	123.4	2880	104.1	3660	81.92	4560	65.75
1990	150.7	2440	122.9	2890	103.7	3680	81.47	4580	65.46
2000	149.9	2450	122.4	2900	103.4	3700	81.03	4600	65.18
2010	149.2	2460	121.9	2910	103.0	3720	80.60	4620	64.90
2020	148.4	2470	121.4	2920	102.7	3740	80.17	4640	64.62
2030	147.7	2480	120.9	2930	102.3	3760	79.74	4660	64.34
2040	147.0	2490	120.4	2940	102.0	3780	79.32	4680	64.06
2050	146.3	2500	119.9	2950	101.6	3800	78.90	4700	63.79
2060	145.5	2510	119.5	2960	101.3	3820	78.49	4720	63.52
2070	144.8	2520	119.0	2970	100.9	3840	78.08	4740	63.25
2080	144.1	2530	118.5	2980	100.6	3860	77.67	4760	62.99
2090	143.5	2540	118.0	2990	100.3	3880	77.27	4780	62.72
2100	142.8	2550	117.6	3000	99.94	3900	76.88	4800	62.46
2110	142.1	2560	117.1	3020	99.28	3920	76.49	4820	62.20
2120	141.4	2570	116.7	3040	98.62	3940	76.10	4840	61.95
2130	140.8	2580	116.2	3060	97.98	3960	75.71	4860	61.69
2140	140.1	2590	115.8	3080	97.34	3980	75.33	4880	61.44
2150	139.5	2600	115.3	3100	96.72	4000	74.96	4900	61.19
2160	138.8	2610	114.9	3120	96.10	4020	74.58	4920	60.94
2170	138.1	2620	114.4	3140	95.48	4040	74.21	4940	60.69
2180	137.5	2630	114.0	3160	94.88	4060	73.85	4960	60.45
2190	136.9	2640	113.6	3180	94.28	4080	73.49	4980	60.20
2200	136.3	2650	113.1	3200	93.69	4100	73.13	5000	59.96
2210	135.7	2660	112.7	3220	93.11	4120	72.77	5050	59.37
2220	135.1	2670	112.3	3240	92.54	4140	72.42	5100	58.79
2230	134.4	2680	111.9	3260	91.97	4160	72.07	5150	58.22
2240	133.8	2690	111.5	3280	91.41	4180	71.73	5200	57.66
2250	133.3	2700	111.0	3300	90.86	4200	71.39	5250	57.11
2260	132.7	2710	110.6	3320	90.31	4220	71.05	5300	56.75
2270	132.1	2720	110.2	3340	89.77	4240	70.71	5350	56.04
2280	131.5	2730	109.8	3360	89.23	4260	70.38	5400	55.52
2290	130.9	2740	109.4	3380	88.70	4280	70.05	5450	55.01
2300	130.4	2750	109.0	3400	88.18	4300	69.73	5476	54.76
2310	129.8	2760	108.6	3420	87.67	4320	69.40	5500	54.51
2320	129.2	2770	108.2	3440	87.16	4340	69.08	5550	54.02
2330	128.7	2780	107.8	3460	86.65	4360	68.77	5600	53.54
2340	128.1	2790	107.5	3480	86.16	4380	68.45	5650	53.07
2350	127.6	2800	107.1	3500	85.66	4400	68.14	5700	52.60
2360	127.0	2810	106.7	3520	85.18	4420	67.83	5750	52.14
2370	126.5	2820	106.3	3540	84.70	4440	67.53	5800	51.69
2380	126.0	2830	105.9	3560	84.22	4460	67.22	5850	51.25
2390	125.4	2840	105.6	3580	83.75	4480	66.91	5900	50.82
2400	124.9	2850	105.2	3600	83.28	4500	66.63	5950	50.39
2410	124.4	2860	104.8	3620	82.82	4520	66.33	6000	49.97
2420	123.9	2870	104.5	3640	82.37	4540	66.04	6050	49.56

EQUIVALENT VALUES—*Continued*

6100	49.15	6900	43.45	7700	38.94	8500	35.27	9300	32.24
6150	48.75	6950	43.14	7750	38.69	8550	35.07	9350	32.70
6200	48.36	7000	42.83	7800	38.44	8600	34.86	9400	31.90
6250	47.97	7050	42.53	7850	38.19	8650	34.66	9450	31.73
6300	47.59	7100	42.23	7900	37.95	8700	34.46	9500	31.56
6350	47.22	7150	41.93	7950	37.71	8750	34.27	9550	31.39
6400	46.85	7200	41.64	8000	37.48	8800	34.07	9600	31.23
6450	46.48	7250	41.35	8050	37.25	8850	33.88	9650	31.07
6500	46.13	7300	41.07	8100	37.02	8900	33.69	9700	30.91
6550	45.77	7350	40.79	8150	36.79	8950	33.50	9750	30.75
6600	45.43	7400	40.52	8200	36.56	9000	33.31	9800	30.59
6650	45.09	7450	40.24	8250	36.34	9050	33.13	9850	30.44
6700	44.75	7500	39.98	8300	36.12	9100	32.95	9900	30.28
6750	44.42	7550	39.71	8350	35.91	9150	32.77	9950	30.13
6800	44.09	7600	39.45	8400	35.69	9200	32.59	10000	29.98
6850	43.77	7650	39.19	8450	35.48	9250	32.41		

NATIONAL FIRE PROTECTION ASSOCIATION

Available for release, April 29, 1922.

Electrical Committee
Dana Pierce, Chairman
Report of Standing Committee on Signal Systems, Wireless and Lightning

COMMITTEE

William S. Boyd, Chairman
175 West Jackson Boulevard, Chicago, Ill.

J. M. Curtin
C. W. Mitchell
F. A. Raymond
Ralph Sweetland

To Electrical Inspectors:

The following report of the Technical Sub-Committee on Radio Equipment (National Electrical Code, Rule 86) has been approved by the Standing Committee on Signal Systems, Wireless and Lightning, and in co-operation with Mr. Dana Pierce, Chairman of the Electrical Committee, is promulgated in order to produce field experience to substantiate the wisdom of the proposed rules before final submission to the Electrical Committee for incorporation into the 1923 edition of the National Electrical Code. Neither the Standing Committee nor the Electrical Committee has authority to suspend or replace the present Rule 86 of the National Electric Code, but this report is issued by the authority granted to the Chairman of the Standing Committee and the Chairman of the Electrical Committee for the information of inspection departments having jurisdiction over the application of the Code.

Suggestions for improvements in these proposed rules should be sent to Mr. William S. Boyd, Chairman, 175 W. Jackson Boulevard, Chicago, not later than September 1, 1922.

(Sgd.) DANA PIERCE, *Chairman,*
Electrical Committee, N. F. P. A.

(Sgd.) WILLIAM S. BOYD, *Chairman,*
Standing Committee on Signal Systems,
Wireless and Lightning.

CORRECTED FINAL REPORT

The following requirements are submitted as proposed revisions of Rule 86, National Electrical Code:

RULE 86, RADIO EQUIPMENT

NOTE: These rules do not apply to Radio Equipment installed on ship-board.

In setting up radio equipment all wiring pertaining thereto must conform to the general requirements of this code for the class of work installed and the following additional specifications:

FOR RECEIVING STATIONS ONLY

Antenna

a. Antennas outside of buildings shall not cross over or under electric light or power wires of any circuit of more than six hundred (600) volts or railway trolley or feeder wires nor shall it be so located that a failure of either antenna or of the above-mentioned electric light or power wires can result in a contact between the antenna and such electric light or power wires.

Antennas shall be constructed and installed in a strong and durable manner and shall be so located as

to prevent accidental contact with light and power wires by sagging or swinging.

Splices and joints in the antenna span, unless made with approved clamps or splicing devices, shall be soldered.

Antennas installed inside of buildings are not covered by the above specifications.

Lead-in Wires

b. Lead-in wires shall be of copper, approved copper-clad steel or other approved metal which will not corrode excessively and in no case shall they be smaller than No. 14 B. & S. gauge except that approved copper-clad steel not less than No. 17 B. & S. gauge may be used.

Lead-in wires on the outside of buildings shall not come nearer than four (4) inches to electric light and power wires unless separated therefrom by a continuous and firmly fixed non-conductor that will maintain permanent separation. The non-conductor shall be in addition to any insulation on the wire.

Lead-in wires shall enter building through a non-combustible, non-absorptive insulating bushing.

Protective Device

c. Each lead-in wire shall be provided with an approved protective device properly connected and located (inside or outside the building) as near as practicable to the point where the wire enters the building. The protector shall not be placed in the immediate vicinity of easily ignitible stuff, or where exposed to inflammable gases or dust or flyings of combustible materials.

The protective device shall be an approved lightning arrester which will operate at a potential of five hundred (500) volts or less.

The use of an antenna grounding switch is desirable, but does not obviate the necessity for the approved protective device required in this section. The antenna grounding switch if installed shall, in its closed position, form a shunt around the protective device.

Protective Ground Wire

d. The ground wire may be bare or insulated and shall be of copper or approved copper-clad steel. If of copper the ground wire shall be not smaller than No. 14 B. & S. gauge, and if of approved copper-clad steel it shall not be smaller than No. 17 B. & S. gauge. The ground wire shall be run in as straight a line as possible to a good permanent ground. Preference shall be given to water piping. Gas piping shall not be used for grounding protective devices. Other permissible grounds are grounded steel frames of buildings or other grounded metallic work in the building and artificial grounds such as driven pipes, plates, cones, etc.

The ground wire shall be protected against mechanical injury. An approved ground clamp shall be used wherever the ground wire is connected to pipes or piping.

Wires Inside Buildings

e. Wires inside buildings shall be securely fastened in a workmanlike manner and shall not come nearer than two (2) inches to any electric light or power wire unless separated therefrom by some continuous and firmly fixed non-conductor making a permanent separation. This non-conductor shall be in addition to any regular insulation on the wire. Porcelain tubing or approved flexible tubing may be used for encasing wires to comply with this rule.

Receiving Equipment Ground Wire

f. The ground conductor may be bare or insulated and shall be of copper, approved copper-clad steel or other approved metal which will not corrode excessively under existing conditions, and in no case shall the ground wire be less than No. 14 B. & S. gauge except that approved copper-clad steel not less than No. 17 B. & S. gauge may be used.

The ground wire may be run inside or outside of building. When receiving equipment ground wire is run in full compliance with rules for Protective Ground Wire, in Section *d*, it may be used as the ground conductor for the protective device.

FOR TRANSMITTING STATIONS

Antenna

g. Antennas outside of buildings shall not cross over or under electric light or power wires of any circuit of more than six hundred (600) volts or railway trolley or feeder wires, nor shall it be so located that a failure of either the antenna or of the above-mentioned electric light or power wires can result in a contact between the antenna and such electric light or power wires.

Antennas shall be constructed and installed in a strong and durable manner and shall be so located as to prevent accidental contact with light and power wires by sagging or swinging.

Splices and joints in the antenna span shall, unless made with approved clamps or splicing devices, be soldered.

Lead-in Wires

h. Lead-in wires shall be of copper, approved copper-clad steel or other metal which will not corrode

excessively and in no case shall they be smaller than No. 14 B. & S. gauge.

Antenna and counterpoise conductors and wires leading therefrom to ground switch, where attached to buildings, must be firmly mounted five (5) inches clear of the surface of the building, on non-absorptive insulating supports such as treated wood pins or brackets equipped with insulators having not less than five (5) inch creepage and air gap distance to inflammable or conducting material. Where desired approved suspension type insulators may be used.

i. In passing the antenna or counterpoise lead-in into the building a tube or bushing of non-absorptive insulating material shall be used and shall be installed so as to have a creepage and air-gap distance of at least five (5) inches to any extraneous body. If porcelain or other fragile material is used it shall be installed so as to be protected from mechanical injury. A drilled window pane may be used in place of bushing provided five (5) inch creepage and air-gap distance is maintained.

Protective Grounding Switch

j. A double-throw knife switch having a break distance of four (4) inches and a blade not less than one-eighth (⅛) inch by one-half (½) inch shall be used to join the antenna and counterpoise lead-ins to the ground conductor. The switch may be located inside or outside the building. The base of the switch shall be of non-absorptive insulating material. Slate base switches are not recommended. This switch must be so mounted that its current-carrying parts will be at least five (5) inches clear of the building wall or other conductors and located preferably in the most direct line between the lead-in conductors

and the point where ground connection is made. The conductor from grounding switch to ground connection must be securely supported.

Protective Ground Wire

k. Antenna and counterpoise conductors must be effectively and permanently grounded at all times when station is not in actual operation (unattended) by a conductor at least as large as the lead-in, and in no case shall it be smaller than No. 14 B. & S. gauge copper or approved copper-clad steel. This ground wire need not be insulated or mounted on insulating supports. The ground wire shall be run in as straight a line as possible to a good permanent ground. Preference shall be given to water piping. Gas piping shall not be used for the ground connection. Other permissible grounds are the grounded steel frames of buildings and other grounded metal work in buildings and artificial grounding devices such as driven pipes, plates, cones, etc. The ground wire shall be protected against mechanical injury. An approved ground clamp shall be used wherever the ground wire is connected to pipes or piping.

Operating Ground Wire

l. The radio operating ground conductor shall be of copper strip not less than three-eighths (⅜) inch wide by one-sixty-fourth (1/64) inch thick, or of copper or approved copper-clad steel having a periphery or girth (around the outside) of at least three-quarters (¾) inch (for example, a No. 2 B. & S. gauge wire) and shall be firmly secured in place throughout its length. The radio operating ground conductor shall be protected and supported similar to the lead-in conductors.

Operating Ground

m. The operating ground conductor shall be connected to a good permanent ground. Preference shall be given to water piping. Gas piping shall not be used for ground connections. Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building and artificial grounding devices such as driven pipes, plates, cones, etc.

Power from Street Mains

n. When the current supply is obtained directly from street mains, the circuit shall be installed in approved metal conduit, armored cable or metal raceways.

If lead covered wire is used, it shall be protected throughout its length in approved metal conduit or metal raceways.

Protection from Surges, Etc.

o. In order to protect the supply system from high-potential surges and kick-backs there must be installed in the supply line as near as possible to each radio-transformer, rotary spark-gap, motor in generator sets and other auxiliary apparatus one of the following:

1. Two condensers, each of not less than one-half (½) microfarad capacity and capable of withstanding six hundred (600) volt test, in series across the line and mid-point between condensers grounded; across (in parallel with) each of these condensers shall be connected a shunting fixed spark-gap capable of not more than one-thirty-second (1/32) inch separation.

2. Two vacuum tube type protectors in series across the line with the mid-point grounded.

3. Non-inductively wound resistors connected across the line with mid-point grounded.

4. Electrolytic lightning arresters such as the aluminum cell type.

In no case shall the ground wire of surge and kick-back protective devices be run in parallel with the operating ground wire when within a distance of thirty (30) feet.

The ground wire of the surge and kick-back protective devices shall not be connected to the operating ground or ground wire.

Suitable Devices

p. Transformers, voltage reducers, keys and other devices employed shall be of types suitable for radio operation.

GENERAL INDEX

PAGE

"A" Battery 8
Aerial, *See* Antenna
Alternating current 43
Alternator, high frequency 46, 72
Ammeter 105
Ampere, definition of 118
Amplifier—
  Audio frequency 8, 16, 31
  Microphone 105
  Speech 108
Amplifying apparatus 8, 16, 30, 31, 105, 108
Amplitude, definition of 93
Analogy between vibrating physical objects and radio waves 42
Antenna—
  Ammeter 105
  Capacity of 117
  Fan 66
  For receiving sets 55
  For transmitters 62, 63
  Loop 11, 60
  Losses in 53, 55
  Resistance of 118
  Size of 59
  Supports for 59
  Triangular 66
  Rules to observe in erection of 66
  Umbrella 66
  Wavelength of 117
Arc—
  Poulsen 46
  Theory of 82
  Transmitter 79
Audio frequency amplifiers 8, 16, 30, 31, 105, 108

	Page
Audion—	
Oscillating	47, 93
Receiver, selective, with regeneration	27
Simplest circuit	27
Theory of, as generator	93
Battery eliminators	8
"B" Battery	27
Protection	112
Bias, grid	78
Bureau of Posts	115
Buzzer	99, 114
Bypass condenser	31, 108
Cage antenna	63
Capacity ground	69
Carrier wave	50, 93
"C" Battery	35, 78
Chemical rectifier	89
Choice of receiver	7
Chokes—	
Constant current	103, 107
Radio frequency	76, 84, 107
Circuit diagrams	24
Classification of receivers	7
Code, international telegraph	120
Completely modulated	
Transmitter	89
Wave	78
Condensers—	
Bypass	108
Construction of	112
Parallel connection of	117
Series connection of	117
Series	105
Stopping	84
Constant current choke	103
Coulomb, definition of	119
Counterpoise	69
Insulation of	71
Size of	71
Crystal receivers	7
Selective	24

PAGE

Current supply—
- Battery eliminator 8
- Dry batteries 8
- Storage batteries 8

Damped waves—
- Advantages of 48
- Disadvantages of 48

Damped wave transmission 46
Decrement, definition of 97
Definitions of electrical terms 118
Direct current 43
Distortion in radio telephone—
- Elimination of 105

Driver, radio frequency 115

Elaborate telephone transmitter 105
Electrocution, precautions against 60
Electrolytic rectifier 89
Ether 18, 43
Equivalent values—
- Kilocycles to meters and vice versa 121

External rectifiers 89

Farad, definition of 119
Faults, correction of 31, 110
Filament supply 84, 107
Filters 91
Ford coil, use of 111
Frequency, conversion of, to wavelength 47
Fuses for plate supply 112

Grid—
- Coil 110
- Condenser 27, 78, 105
- Leak 27, 78
- Modulation 101
- Resistance 105

Ground clamp 67
Grounds—
- Artificial 67
- Capacity 69
- For receiving sets 66

Harmonics 55

PAGE

Hartley—
Circuit 82
Mr. R. V. L. 82
Heising—
Modulation 101
Mr. R. A. 101
Helix 78
Henry, definition of 119
Honeycomb coils 76
Horsepower, definition of 119

Impregnation of delicate parts for Philippines 16
Insulator—
Antenna 112
Lead in 112
Interference—
Natural 51
Radio 52
Static 51
International telegraph code 120
Inverted L antenna 63

Kenotron rectifier 89
Keying of C. W. transmitter 85
Kilocycles to meters 121

Lead in insulators 112
Life of tubes 9
Lighting circuits, use of, as antenna 62
Loop antenna 11, 60
Loose coupling 52
Loud speaker 15

Makeshift apparatus 111
Manila lighting supply used for plates 85
Masts, for antenna 59, 60
Meters, inexpensive 112
Meters to kilocycles 121
Microphone—
Definition of 97
Amplifier 105
Microphones, resistance of 99
Milliammeter 107

PAGE

Modulation—
- Definition of 93
- Grid 101
- Methods of 97
- Plate 101
- Theory of plate 103

Neon tube 114
Number of tubes in telephone transmitter 101

Ohm, definition of 118
Ohm's law, use of 116
Open circuits, test for 112
Oscillating audion 47
Oscillations, parasitic 110

Parallel—
- Condensers in 117
- Resistances in 117
- Tubes in 110

Parasitic oscillations 110
Parts of telephone transmitter 97
"Pi", definition of 119
Plate modulation 101
Plate supplies—
- Comparison of 84

Plate voltage—
- Warning against use of excessive, in Philippines .. 31

Polarity of D. C. supply, test for 111
Power supplies for audion transmitters 85
Price of receiving equipment 14

Radio frequency—
- Methods of changing low frequency A. C. to 73

Radio frequency receivers—
- General classification 10

Radio frequency waves—
- Conversion of into sound waves 49
- Types of 95

Radio telephone, age of 99
Range of receivers in Philippines 41
Reactors, smoothing 89

	Page
Receivers—	
Audion, non-regenerative	9
Audion, regenerative	8
Crystal	8
Description of telephone	49
Neutrodyne	12, 33
Radio frequency	11
Range of in Philippines	41
Reflex	10
Reflex with crystal detector	33
Requirements of good	12
Short wave	35
Simplest	24
Super heterodyne	12, 38
Rectifiers	50
External	89
Kenotron	89
Chemical	89
Electrolytic	89
"S" tube	89
Regulations, underwriters'	124
Resistance of microphones	99
Resistances—	
Parallel connection of	117
Series connection of	117
Resonant circuit, the	17
Rule for No. of tubes in telephone transmitter	101
Selection of apparatus	14, 16
Self-rectification—	
Full wave	76, 89
Half wave	85
Short circuits, test for	112
Short wave receiver	35
Simplest receiver	24
Single layer chokes	76, 84
Single tube receiver	7
Sinusoidal curves	43
Smoothing reactor	89
Soldering arc	112
Spark coil	79
Decrement of	79

	Page
Speech amplifier	108
Speed of radio waves	42
Starting operation of transmitter	110
Static	41
Stopping condenser	84
"S" tube rectifier	89
Substitutes	111
Super Heterodyne—	
Theory of	38
Reasons for superiority of	40
"Sure fire" oscillator	84
Symbols, conventional radio	21, 22
Telegraph code, international	120
Telephone transmitter, elaborate	105
Telephone—	
Radio	93
Use of, as antenna	62
Theory of—	
Arc transmitter	82
Plate modulation	103
Radio	17
Tickler connections	110
Transmitters—	
Arc	79
Audion	76, 82
Direct current supply for	79
Emergency	79
Parts of telephone	97
Power supply for	85
Simple	72
Spark	73
Trouble, locating: *See* Faults, correction of.	
Turn ratio	16
"T" type antenna	63
Umbrella antenna	66
Undamped waves—	
Advantages of	48
Disadvantages of	49
Undamped wave transmitters	46
Underwriters' regulations	124

Volt, definition of 118
Voltage, rough test for 111
Voltmeter, filament 108

Watt, definition of 119
Wave form of radio waves 43
Wavelength, conversion of, to frequency 47
Wavemeters, constructional details 114
Waves, types of R. F. 95

INDEX TO DRAWINGS

	Page
Absorption modulation	100
Alternator transmitter	74
Antenna construction	54, 64, 65
Antenna for receivers	58
Antenna losses	56, 57
Arc, Poulsen	81
Audio frequency amplifier	29
Audion circuit, simplest	26
Audion receiver, with regeneration	28
Audion transmitters	77, 83
Counterpoise construction	70
Crystal receiver, selective	25
Elaborate telephone transmitter	106
Filter system	92
Grid modulation	102
Ground connection	68
Loop antenna	61
Neutrodyne circuit	34
Oscillating audion	94
Plate modulation	104
Power supply	86, 87
Radio waves, types of	45, 96
Reactance coupled amplifier	109
Rectifiers	88,90
Reflex receiver	32
Resonant circuit	19
Short wave receiver	36, 37
Simplest receiver	23
Spark coil	80
Spark transmitter	75
Super Heterodyne	39
Symbols, conventional	21, 22
Telephone, simple	98
Tuning to resonance	20
Wave forms	44
Wavemeter circuits	113